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R.A.R.D.E. MEMORANDUM 10/70

Measurement of RF pick up. Improved equipment for assessment of  
RF hazard in firing circuits of weapons containing  
wire-bridge electrically initiated explosive devices (EIED)

(title UNCLASSIFIED)

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Edited by M. G. Brown, B.Tech, Grad Inst P

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Measurement of RF pick up. Improved equipment for assessment of RF hazard in firing circuits of weapons containing wire-bridge electrically initiated explosive devices (EIED) (U)

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Edited by M.G. Brown, B Tech, Grad Inst P (E1)

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Summary

The EMI Hazard Measuring Equipment for use on r f trials, described in R.A.R.D.E. Memorandum 29/69, has been improved and the Mk.2 equipment is described. The new equipment monitors the r f hazard using a thermistor attached to the bridge-wire. The thermistor forms the active arm of a d c bridge and the output of this bridge gives frequency modulation of a pulse generator contained within the weapon under test. These pulses are conveyed to a remote indicator by a magnetic and acoustic link where they are integrated and displayed as a d c signal on the hazard meter. A remote 'zeroing' facility is provided at the indicator unit allowing the bridge to be balanced under conditions of zero hazard.

This memorandum describes work carried out by Messrs EMI (Electronics) Ltd under Min Tech contract No KV/B/378/CB64(a). It is one of the series entitled "EIED and RF Hazards" and is based upon material published, on limited circulation, in Refs 4, 5, 6, 7 and 8.

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## CONTENTS

	<u>Page</u>
1. Introduction	1
2. The EMI Hazard Measuring Equipment Mk 1 (HME1)	
2.1 Fundamental Principles	1
2.2 Advantages of the HME1	3
2.3 Disadvantages of the HME1	3
2.4 Design Requirement for an Improved Hazard Measuring Equipment	5
3. The EMI Hazard Measuring Equipment Mk 2 (HME2)	4
3.1 Fundamental principles	4
3.2 Instrumentation of the dummy igniter	5
3.3 The Data Coding Module	6
3.4 The Magnetic Link	6
3.5 The Amplifier Module	6
3.6 The Indicator Unit	7
3.7 Power Supplies	9
3.7.1 Data Coding and Amplifier Modules	9
3.7.2 The Indicator Unit	9
3.8 Mechanical Construction	9
4. Use of the Equipment	9
4.1 Installation	9
4.2 Operation	10
5. Performance	10
5.1 Sensitivity	10
5.2 Dynamic Range	11
5.3 Frequency Response	11
5.3.1 Type 203 Igniter	11
5.3.2 ICI F53 Fuse, Electric	11
5.3.3 Summary and Future Work	12
5.4 Data link	12
5.5 General Capability	12

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CONTENTS (Continued)

	<u>Page</u>
6. Use of the HME2 with the Conducting Composition Voltage Detector (CCVD)	13
6.1 Present State of the Art	13
6.2 Future Work	13
7. Conclusions	13
8. Bibliography	14
Appendix 1 Technical Specification of HME2	15
Figs 1-21	

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## 1. INTRODUCTION

An EIED is designed such that it will normally operate only when it receives an electrical stimulus sufficient to raise the temperature of the explosive above a certain critical value. The electrical stimulus is provided by a firing circuit which, under certain conditions may act as an aerial. In the presence of the very high r f fields to be encountered in the vicinity of modern military radar and radio transmitters, this aerial might pick up sufficient power or energy to cause premature initiation of the EIED.

It is thus desirable that equipment be available for monitoring the electrical power induced in the EIED when it is positioned within the weapon. Such an equipment, whilst giving an accurate and reproducible measure of the r f hazard, must not perturb the r f field in which the weapon is immersed during the trial.

With all EIED it is possible to determine a threshold power and/or energy which will give a probability of firing of 0.1% with 95% confidence (Ref 1).

It was agreed with the Ordnance Board that a hazardous situation existed if, under r f hazard trial conditions, the power induced in the bridge-wire was not at least 20 dB down on the threshold power; similarly, for the voltage sensitive cc devices, the voltage measured in an r f trial should be at least 20 dB down on the threshold voltage.

Five techniques have been used in r f hazard trials:

- a. Go - no go tests
- b. Temperature sensitive paints
- c. The induced current detector unit
- d. The RAE vacuum thermocouple technique
- e. The EMI hazard measuring equipment

The first four systems were discussed briefly in a previous memorandum in this series (Ref 2) the main subject of which was the EMI hazard measuring equipment. The present memorandum describes the development and proving trials at EMI(E), of a Mark II hazard measuring equipment which overcame many of the disadvantages of the earlier equipment.

Before describing the new equipment a brief summary, together with the main advantages and disadvantages, will be given of the Hazard Measuring Equipment Mk 1.

2. THE EMI(E) HAZARD MEASURING EQUIPMENT MK 1 (HME1)2.1 Fundamental Principles

This equipment was designed specifically for the assessment of the r f hazard associated with the ICI F53 fuse, electric, which is basically the type E fusehead shown in Fig 1, and the conducting composition N8 igniter, shown in Fig 2; capability of the equipment was subsequently extended to include the type 203 igniter shown in Fig 3.

Both the F53 and the type 203 rely for their operation on an electrically heated bridge-wire in contact with the explosive. The method employed with the wire bridge devices was to replace the Service EIED with an instrumented dummy igniter.

A thermistor bead, cemented to the bridge-wire of the instrumented device monitored the temperature of the bridge-wire and this parameter was used to define the r f hazard. Having established that the thermistor bead, and associated instrumentation, did not affect the impedance/frequency response of the device, resistance, and hence temperature, monitoring was performed using an a c bridge; the active arm of this bridge was the bridge-wire thermistor. A second thermistor carefully selected to match the thermal response of the bridge-wire thermistor, was placed in close proximity to the bridge-wire and constituted a balancing arm of the bridge giving ambient temperature compensation.

A block diagram of the HME1 is shown at Fig 4. The thermistor bridge was fed by a 3.000 KHz oscillator and the out-of balance signal, due to increased bridge-wire temperature, was amplified and compared with a 3.063 KHz reference signal. The two oscillators and the amplifier were contained in the oscillator module the output of which, consisting of the combined reference and out-of-balance signal, was fed to the primary windings of a split core transformer. This half core was placed against the inner surface of the weapon skin whilst a second half core, carrying an identical winding was aligned with the first on the outside of the skin. Sufficient magnetic flux penetrated the skin to induce a workable current in the outside winding. The induced signal was then amplified using a tuned amplifier incorporating an AGC loop operating on the reference signal. The output of this amplifier drove an electro-acoustic transducer (speaker) the audio output of which was transmitted down a plastic acoustic link to a remote receiving transducer (microphone).

The electrical output of the receiving transducer passed to the indicator unit via a screened input selector which allowed for up to six channels to feed the same indicator.

The indicator unit had a 3 KHz broad band, tuned amplifier incorporating an AGC loop which maintained the level of the reference signal constant at the output. The out-of-balance and reference signals were added in a mixer and the 63 Hz beat signal was amplified in a tuned amplifier the output of which was displayed on a meter. By maintaining the reference signal constant at the indicator unit all gain variations throughout the system could be ignored.

The relationship between meter reading and power dissipated in the bridge-wire was obtained by injecting known quantities of d c into the instrumented igniter and noting the reading on the hazard meter.

For use with the voltage sensitive cc igniter an inert igniter was instrumented with a diode voltmeter. This conducting composition voltage detector (CCVD) is described in detail in Ref 3 where it is pointed out that the geometry of the diode voltmeter imposed an upper frequency limitation of 500 MHz. Recently a report has been issued by Messrs EMI(E) (Ref 4) describing new instrumentation which has raised the upper frequency limit to 1.8 GHz. When used with the HME1 the d c output from the diode voltmeter was passed to a chopper module, which, using the 3 KHz oscillator signal, alternately shorted and open circuited the voltmeter output. The resulting chopped d c was then treated in the same way as was the 3 KHz output from the thermistor bridge.

Calibration of the equipment using the CCVD was very complex and was described in detail in Ref 3.

2.2 Advantages of the HME1

2.2.1 The bridge-wire used was the same as that used in the Service EIED and the circuit under test was therefore not affected by insertion of the instrumented igniter.

2.2.2 The pick-up information was transmitted through the weapon skin without necessitating the provision of holes which would disturb the r f field conditions.

2.2.3 The coupling link from the missile to the remote indicator unit was of plastic and therefore had no effect on the e m field outside the missile.

2.2.4 The operator, being remote from the missile, did not disturb the e m field and neither was he exposed to strong e m fields which could constitute a biological hazard.

2.2.5 Both in the case of the wire bridge devices and the cc igniter the equipment was capable of detecting signals more than 20 dB below the threshold values; the ultimate sensitivity being in the region of 25 dB below the threshold of the F53 fuse, electric.

2.3 Disadvantages of the HME1

2.3.1 It was found in practice that a greater sensitivity would be desirable to facilitate the search for worst conditions in an r f hazard trial (see section 4.2(4)).

2.3.2 The system relied upon accurate balancing of the a c bridge under conditions of zero hazard and, since thermistors cannot be produced having identical resistance and thermal co-efficients of resistance, it was necessary to include extra circuitry to ensure that, at all ambient temperatures to be encountered, the two thermistors would 'track' ie appear to have the same resistance. To this end matching thermistors were selected using a computer programme such that they were balanced to within 5 ohms at any ambient temperature within the range 0 to 30 °C.

The sensitivity limitation, section 2.3.1, was due partly to the fact that the two thermistors were not affected equally by the ambient temperature, particularly when it was changing rapidly.

2.3.3 As the instrumentation circuit contained reactive components the a c bridge required phase as well as amplitude control.

2.3.4 The battery life of the inaccessible modules was only 80 hours which in a long trial was an embarrassment.

2.3.5 Probably the greatest disadvantage was the impossibility of checking and, if necessary, resetting the zero once the equipment was assembled within the weapon.

## 2.4 Design Requirement for an improved Hazard Measuring Equipment

With the experience gained on the HMEI work was undertaken at EMI(E) Ltd to develop an improved Mk 2 equipment which, whilst possessing all the advantages of the Mk 1 equipment, overcame the shortcomings described in Sect 2.3 above. This Mk 2 equipment was intended to have the following advantages compared with the Mk 1:

- a. Increased sensitivity
- b. Elimination of the thermistor selection procedures which required accurate measurements and computer processing.
- c. Facility at the read-out unit to compensate for bridge imbalance due to ambient temperature changes
- d. Reduced module size
- e. Increased battery life.

The following performance targets were defined to achieve the above advantages:

- i. Sensitivity at least 40 dB down on the threshold firing levels of both the F53 fuse, electric and the type 203 igniter
- ii. Dynamic range of 25 dB
- iii. Internal module battery life of at least two weeks continuous running
- iv. Operating ambient temperature range of 0 to 30°C.

## 3. THE EMI HAZARD MEASURING EQUIPMENT MK 2 (HME2)

### 3.1 Fundamental Principles

To achieve the requirements detailed above the HME2 employs a d c thermistor bridge; thus eliminating phase balancing problems. The out of balance signal from the d c bridge is used to modulate the frequency of a train of pulses and information concerning the state of balance of the thermistor bridge, ie the temperature of the bridge-wire, is conveyed to a remote indicator as a frequency modulated pulse train.

Fig 5 is a block diagram of the Mk 2 equipment. The d c output of the thermistor bridge is amplified and used to control the frequency of a pulse generator located in the data coding module. When both thermistors are at the same temperature, under conditions of zero hazard, a constant pulse frequency is produced. When an induced current raises the temperature of the bridge-wire, the d c bridge becomes unbalanced and the pulse frequency changes. The pulses are fed via a split core transformer and acoustic link to the indicator unit. The split core transformer and acoustic link techniques were used on the earlier equipment and only minor modifications were required.

The incoming pulses are amplified and integrated in the indicator unit and before commencing a trial the resultant d c from the indicator is 'backed-off' under conditions of zero hazard. This 'backing-off' facility enables remote corrections for ambient temperature changes to be made. Once the system has been 'zeroed' heating of the bridge-wire causes unbalance of the thermistor bridge which gives rise to an increase in voltage from the integrator network; this increase is displayed on the output meter.

Calibration of the HME2 is identical to that described for the HME1 (Ref 2), and is achieved by injecting known quantities of d c into the instrumented igniter. Discussion of the use of HME2 with the c c igniter is deferred until section 6.

The battery drain for the data coding module, inaccessible during trials, was checked and tests indicated a battery life approaching three weeks.

If the missile skin possesses a suitably located aperture, ie the missile screening is not continuous, the magnetic link and the amplifier module may be omitted and a direct connection made between the data coding module and the electro-acoustic transducer; this facility was available on the HME1. Figures 6 and 7 show general views of the HME2 with and without the magnetic link. Appendix 1 details the technical specification of the HME2 and, as the remote zeroing facility enables thermistors to be chosen in a much less stringent fashion, the design requirements have all been met.

### 3.2 Instrumentation of the Dummy Igniter

The instrumentation, on both the supported type 203 and unsupported F53, wire bridge devices consists of a small thermistor cemented to the bridge-wire with a second thermistor located nearby; this latter giving ambient temperature compensation. Also incorporated in the instrumentation are r f filters which de-couple the bridge-wire and its leads from the thermistors and their leads. The whole assembly is located within the normal geometry of the Service EIED.

Fig 8 is a schematic drawing of the 203 igniter bridge-wire instrumentation. The components are attached, by their leads, to a printed circuit board, 0.45 x 0.50cm. The instrumentation circuit diagram is given at Fig 9. The sensing thermistor is cemented to the wire bridge and connected to the circuit board, the compensating thermistor and the two filtering capacitors are potted in araldite and three instrumentation leads emerge from the igniter at the end opposite to the firing leads. This instrumented header is then inserted into the relevant housing; in the case of the type 203 igniter this is the normal brass body but for the F53 fuses, electric a synthetic resin bonded fibre tube replaces the normal cardboard tube, giving the assembly greater mechanical strength.

The instrumentation of wire bridge igniters is carried out by Messrs EMI(E) Ltd to individual requirements and Fig 10 shows both types of instrumented devices. Instrumented igniters can be supplied with suitable connectors, adaptors and special cables for direct connection to the data coding module. The choice of units is determined by the particular arrangement of the igniter and its immediate surroundings in the weapon. The instrumented igniter is often contained within a screened enclosure and the instrumentation leads pass through the enclosure via co-axial, chassis mounted connectors, and thence by double screened co-axial cable to the data coding module; thus there is no interference with inherent screening of the service EIED, within the weapon.

In order to keep the range of zero adjustment within reasonable bounds it was decided to use thermistors supplied by the manufacturers as matched pairs. These thermistors are STC Type U23 UDMA, their resistances being matched to within 5% over the temperature range 0 to 30°C.

### 3.3 The Data Coding Module

This module consists of a d c amplifier, a pulse generator and an output driver stage. The circuit diagram of the data coding module is shown at Fig 11.

VT1 and VT2 form a differential amplifier whose inputs are taken from the d c thermistor bridge, connected between PL B and PL C and between PL B and PL D, and the two resistors R5 and R6. The supply voltage to the bridge has a low source impedance required to stabilize the thermistor bridge supply voltage when the resistance of the thermistor varies with ambient temperature (typical values of thermistor resistance at 0 and 30°C are 4K and 1K ohms respectively).

The output from VT 2 is taken to VT 5 which provides a constant current source controlling the pulse repetition frequency (p r f) of the asymmetric, astable circuit formed by VT 6 and VT 7. The p r f is variable between 10 and 100 Hz. The output from VT 6 is fed to the base of VT 8, the driver stage, which acts as a switch connecting the output socket PL E across the supply lines during the short period (approx 200 microsecs) of the pulse generated by VT 6 and VT 7.

The 5.6 volt supply is fed in via PL A and all inputs to, and outputs from, the module are filtered by C1-C5, C7-C11 and L1-L5. Under normal operating conditions the unit draws approximately 1.5 mA from the supply.

The resistor R21 adjusts the d c amplifier balance and R8 adjusts the p r f to approximately 55 Hz when the d c amplifier is balanced. These adjustments are made during manufacture and need no further attention unless it becomes necessary to replace components within the module.

### 3.4 The Magnetic Link

In HME1, the magnetic link consisted of a split core transformer, the primary mounted within the missile and the secondary, located in the amplifier module, aligned with the primary on the external surface of the missile. Both halves consisted of two coils, wound in series opposition on a laminated 'E' core; this minimised the possibility of linkage with external fields which, in view of the low signal power, was necessary to maintain a reasonable signal to noise ratio.

The information in the HME2 is passed as a signal of relatively high power and therefore noise is always a second order effect. The magnetic link on the HME2 is a single winding damped by a 2.7K ohm resistor on a simple 'C' core. Both the primary and secondary windings are identical.

The secondary winding is contained within its own housing and connected to the amplifier module by a double screened, sub-miniature, co-axial cable.

### 3.5 The Amplifier Module

This consists of an amplifier, an output driver and an electro-acoustic transducer (speaker). The circuit diagram of the amplifier module is shown at Fig 12.

VT 2 and VT 3 are the active components of a simple RC coupled amplifier having a gain of approximately 60 dB; gain stability is provided by the resistors R5 and R10.

VT 4 is used as a phase splitter to ensure that whatever polarity of pulse is applied to the input, a positive pulse will appear at the base of VT 5. On receipt of a pulse one of these transistors conducts and draws current through R17 which charges C18 to a voltage corresponding to the peak amplitude of the incoming pulse. A slow discharge path is provided for C18 by the resistor R18 which, given a steady train of incoming pulses, permits the transistor VT 5 or VT 6 to conduct for very short times at the peaks of the pulses. The initial pulse of current required to charge C18 produces a voltage drop across VT 9 which drives it into the 'bottomed' state and current flows through the electro-acoustic transducer T 1 for the duration of the pulse, approximately 200 microsecs. The output stage is de-coupled from the supply line by C11 and R27.

The d c voltage across C18 is used to drive an AGC system comprising VT 7, VT 8 and VT11. VT 7 and VT 8 are a pair of cascaded emitter followers which provide base current for VT 1. This latter acts as a variable resistor whose resistance is controlled by the base current. Thus VT 1 and R1 form a variable attenuator for the input signal arriving at PL C.

D1, D2, D3 and R22 set the operating conditions for the AGC system and provide thermal compensation for the transistors involved in it. An output is taken from the emitter chain of VT 8 which gives an indication of the amount of attenuation being applied and thus, indirectly, of the amplitude of the incoming pulses. This facility can be employed as a means of optimising the alignment of the split core transformer. This signal which appears at PL B, varies between 0.1 and 0.2 volt from a source impedance of approximately 3K ohm. A suitable monitoring instrument is the Avometer Mk 8 set on the 50  $\mu$ A range.

The 5.6 volt supply is fed to the module via PL A and all inputs to and outputs from the module are filtered by C12 - C17 and L1 - L3. When functioning normally the unit draws approximately 1 mA from the supply.

### 3.6 The Indicator Unit

This consists of an amplifier, a pulse shaper, an integrator and a set-zero control. The output is displayed on two 100  $\mu$ A meters. The circuit diagram of the indicator unit is shown in Fig 13.

The signal from the receiving transducer of the acoustic link is received at SKT A which is coupled to the base of VT 1. This transistor is the active component of a R C coupled amplifier with gain stability provided by emitter feed back. The output from VT 1 is coupled to VT 2 which acts as a peak voltage detector providing voltage pulses at the base of VT 3; these pulses correspond in time to the positive peaks of the incoming wave-form. VT 4 and VT 5 form a monostable pulse generator with timing elements C5, R10 and R13. This pulse generator is triggered when VT 3 conducts; the resultant pulses are of constant amplitude and width. An output is taken from VT 4 to feed the integrator formed by D2, R50, R20 and C10. The mean d c voltage appearing across C10 is thus proportional to the input pulse repetition frequency. The voltage between the base of VT 9 and earth is the sum of the negative voltage across C10 and the positive voltage across C9.

The voltage across C9 is governed by the set-zero controls RV 1 and RV 2 which are fed by the constant current generator VT 8, hence ensuring linearity of response. The variable resistor RV 8 sets the operating point for the set-zero system.

The high impedance output of the integrator is matched to the low impedance input of the two stage differential amplifier, VT 10, VT 11, VT 12 and VT 13 by the emitter follower VT 9.

Meter M 1 is fed from the collectors of VT 12 and VT 13 and gives a reading proportional to the unbalance of the thermistor bridge; in order to facilitate the 'zeroing' operation M 1 has an electrical zero at 20% full scale deflexion. The scale is graduated 0-100 from the electrical zero to full scale deflexion and the mechanical zero is marked.

Non-linear feedback, D 3 to D 7, R35 and R36, is applied to the differential amplifier and the initial gain is set by R25, R35 and R36. The diodes D4 - D7 progressively compress the upper portion of the meter scale and D3 restricts the reverse movement of the meter needle.

The capacitors C11 to C14 reduce the band width of the amplifier and smooth out the voltage ripple produced by the integrator. The resistor R48 sets the initial conditions of the differential amplifier such that D3 and D7 are unbiased at electrical zero.

The indicator unit is powered by a self-contained, rechargeable battery, BY 1, via the voltage stabiliser VT 14 and VT 15. The variable resistance RV 4 sets the supply line voltage to 10 volts. According to the state of its charge the voltage on BY 1 varies between 11.5 and 15 and a battery check facility is incorporated which compares a stabilised voltage, developed across D9 with a voltage produced by the divider network R44, R45 and R49; the difference is displayed on meter M 2 when switch S2 is in the appropriate position; the scale of this meter is divided into three regions coloured red, white and green respectively and a reading in the red region indicates that the battery requires recharging. Battery BY 1 is charged via SKT C and the polarity reversal protection diode D8.

The meter M 2 is also used to indicate that a train of pulses, significantly greater than background noise in amplitude, is arriving at the indicator unit and hence that the data link is operational. This is achieved by taking an output from the collector of VT 5, in the pulse generator, to the emitter follower VT 6 whose output is rectified by D1 and smoothed by C8. When the pulse generator is operating VT 7 is turned on by the d c voltage appearing across C8. With S 2 in the appropriate position M 2 forms part of the collector load of VT 7 and will read in the green section when the link is functioning normally.

S 1 is the on-off switch for the unit which, in its 'OFF' position short circuits M 1 to protect it from mechanical shock. Meter M 2 is damped by R51.

Between the inner screen and the inner case are the filtering components which filter all the leads entering the inner case.

### 3.7 Power supplies

#### 3.7.1 Data Coding and Amplifier Modules

These modules are powered by replacable mercury cells which have an operational life of approximately 500 hrs. These batteries are housed in boxes, 2 to each box, external to the modules and connected to them by screened cables. As there is no 'ON-OFF' switch on the data coding module, which is normally inaccessible during a trial, the connection of the battery is left until the last possible moment. All of these batteries must be removed from their boxes when not in use to avoid corrosion of the terminals.

#### 3.7.2 The Indicator Unit

This unit contains an internal, rechargeable, Deac, Ni-Cd battery of capacity 1AH. This gives a normal operational life for a fully charged battery of 70 hours.

### 3.8 Mechanical Construction

Great care has been taken to ensure adequate r f screening of the various units of the telemetry link. The indicator unit is doubly screened; the active components, which are susceptible to r f interference are contained within the inner screen which is a steel casting incorporating a screened filter compartment filled with r f absorbent material. The casting together with the rechargeable battery is mounted on a chassis supported by the front panel, and these are all contained within a standard RAE case. The two meters on the front panel are fitted in enclosures which ensure continuous screening of the unit. The front panel assembly and the RAE case form a completely sealed unit; to achieve this a conducting rubber gasket is employed between the panel and case.

The other modules and containers are constructed of gold plated brass and the leads entering and leaving the two modules are filtered in screened compartments fitted with r f absorbent material. All interconnecting cables are double braided and battery switching of these modules is achieved by connecting or disconnecting the battery leads.

The acoustic link follows HME1 practice in using three co-axial plastic tubes but, in order to facilitate the use of the equipment during trials, the ends are fitted with bayonet connectors.

## 4. USE OF THE EQUIPMENT

### 4.1 Installation

In any given weapon each EIED is normally mounted in an enclosure (S & A unit etc) providing some r f screening. It is therefore essential that replacement of the EIED by the instrumented device must not disturb the normal electromagnetic environment. This is achieved by using screened co-axial leads outside the housing. There is no restriction on lead lengths and the data coding module and battery box can be sited wherever space is available. The half transformer must be located at a suitable point on the inner skin of the missile.

If adequate openings are available in the missile skin it is not necessary to use the magnetic link of the amplifier module and, with the provision of appropriate cable, the data coding module can drive the acoustic link sender transducer directly.

When the magnetic link is to be used the amplifier module must be mounted on the outside of the weapon skin in close proximity to the second half transformer. Acoustic links may be positioned wherever it is convenient bearing in mind that, in order to minimise the possibility of extraneous noise (acoustic) affecting the equipment, tubing and transducers should not be allowed to drag along the ground or weapon support. Runs of up to 100 ft of screened lead are permitted from the receiving transducer to the indicator unit.

#### 4.2 Operation

1. Connect the batteries to the data coding and amplifier modules and allow a few minutes for the thermistor bridge to stabilize. If necessary the alignment of the two half cores of the magnetic link may be optimised by adjusting the position of the secondary for maximum reading on an Avometer Mk 8, set to the  $50 \mu\text{A}$  range, monitoring the signal at PL B on the amplifier module (see section 3.5).

2. Switch on the indicator unit and, using the SIG/BATT CH switch in its BATT CH position, check the state of charge of the battery. A fully charged battery will give a reading in the green sector on M 2, the smaller of the two meters, a battery which requires recharging will read in the red sector, whilst a reading in the white sector indicates a battery with only a few hours operational life which should be recharged at the operator's discretion.

NOTE: Before the commencement of any trial the indicator unit battery should be discharged and fully recharged and the mercury cells in the two battery boxes should all be new.

3. Adjust the hazard meter M 1 for electrical zero using the COARSE and FINE, SET ZERO controls.

4. Subject the weapon to the desired r f field and orient for maximum reading on the hazard meter. Note this maximum reading and switch off the transmitter.

5. Repeat the above procedure at all frequencies called for by the trials programme and check the zero setting of the hazard meter after each measurement.

6. With the SIG/BATT CH in the SIG position a train of pulses greater in amplitude than the normal background noise will give a reading in the green portion of meter M2 enabling instant recognition of a potential hazard.

7. Calibrate the system at least daily by injecting known quantities of d c into the instrumented igniter and noting the reading on the hazard meter.

### 5. PERFORMANCE

#### 5.1 Sensitivity

Measurements have shown that the minimum measurable current is never greater than  $3\text{mA}$  RMS in the case of the F 53 fuze, electric and  $17\text{mA}$  RMS in the case of the type 203 igniter; thus, in terms of the threshold values, a sensitivity in excess of  $-40\text{dB}$  has been attained in both cases.

## 5.2 Dynamic Range

Due to the compression of the scale at large deflexions full scale deflexion cannot always be achieved but a dynamic range of at least 26dB is available.

## 5.3 Frequency Response

### 5.3.1 Type 203 Igniter

Using the induced current detector unit (ICDU) as the standard of comparison, connected across an instrumented igniter, r f power was fed to the igniter at different frequencies. At each frequency the power level was adjusted to give the same reading on the hazard meter and the current indicated by the ICDU noted for each frequency. This procedure was followed on two igniters and the results are shown as current indicated by ICDU against current indicated by HME2 in Fig 14.

These results indicate that, on the whole, the HME2 is more sensitive than the ICDU and that the sensitivity difference increases with frequency. However the maximum difference observed is 4.5 dB at 7GHz and only 1.5 dB up to 5 GHz.

A further series of tests were undertaken to determine what effect, if any, the instrumentation had on the induced current appearing at the igniter. For these tests an instrumented and uninstrumented igniter were fed from the same r f power source at different frequencies. The currents flowing in the bridge-wires were both monitored using the ICDU and the results are shown in Fig 15. These results indicate that multiple resonances occur above 5 GHz which do not coincide; however, results obtained on the type E fusehead, using Tempilaq paint as the standard (described below), confirmed that these resonances were due entirely to shortcomings in the ICDU technique.

### 5.3.2 ICI F53 Fuse, Electric

The tests performed on the 203 igniter and described above were repeated for the F53 fuses, electric. Fig 16 shows the comparison between ICDU and HME2. As was the case for the 203 igniter, HME2 is generally more sensitive than the ICDU but the two equipments agree to within 4.5 dB up to a frequency of 4 GHz.

Fig 17 shows the ICDU comparison between instrumented and uninstrumented fuses, electric and it can be seen that large differences appear at frequencies between 2 and 3 GHz and then again above 6 GHz. However, as mentioned in the preceding section, these differences were considered to be artefacts of the experiment, rather than reflecting the effect of the instrumentation, as the filtering components associated with the ICDU considerably modify the igniter response at high frequencies.

To overcome this difficulty a technique employing thermal sensitive paint as the comparison standard was evolved. The tests on the F53 fuse, electric were repeated using 'Tempilaq' paint in place of the ICDU; under laboratory conditions a consistency of about  $\pm 0.5$ dB can be obtained using 'Tempilaq' paint. Fig 18 compares HME2 and 'Tempilaq' paint measurements and indicates that the HME 2 monitors the temperature of, and hence the power dissipated in, the bridge-wire to within 1 dB for frequencies up to 7GHz; this frequency was the upper limit of the rf equipment used and there is no reason to suppose that the situation will worsen at higher frequencies.

Fig 19, which includes a correction obtained from Fig 18, indicates that, up to the maximum attainable frequency of 7 GHz, a difference of no more than 2 dB occurs between the powers arriving at the instrumented and uninstrumented fusehead bridge-wires.

NOTE: An indirect conclusion of this work is that the ICDU is not reliable at frequencies above about 2 GHz.

#### 5.3.3 Summary and Future work

It has been demonstrated that the equipment will indicate to within 2 dB the power that would arrive at an uninstrumented F 53 fuse, electric, up to a frequency of 7 GHz and the power that would arrive at an uninstrumented 203 igniter up to a frequency of 5 GHz. The upper frequency limitation was, in the case of the fusehead, imposed by the available r f equipment and, in the case of the 203 igniter, by the high frequency limitation of the ICDU.

Work has recently commenced at Messrs EMI(E) to extend the frequency range of the comparison by purchasing equipment with a frequency capability of 18 GHz. It is hoped finally to produce HME2/Tempilaq curves up to a frequency of at least 14 GHz.

#### 5.4 Data Link

It was demonstrated that a 10ft acoustic link gave adequate transmission and noise suppression; longer links are considered unnecessary as the length of screened cable which can be employed between the receiving transducer and the indicator unit is virtually unlimited.

#### 5.5 General Capability

A trials schedule was agreed by the Ordnance Board and GW(P&W)5 which utilised the facilities available at A&AEE Boscombe Down. The results of this trial (Ref 5) indicated that the equipment operated satisfactorily over the frequency range 400 KHz to 9.5 GHz; there was no interference to its normal operation due to climatic conditions or immersion in strong r f fields at frequencies in this range.

One channel of this equipment was used, in an actual r f hazard trial by Messrs BAC(0); the operators found no difficulty in using the equipment after a short introductory course and were able to monitor some pick-up at all the frequencies considered. As a result of these trials a few minor modifications were made to increase the robustness of the equipment.

## 6. USE OF THE HME2 WITH THE CONDUCTING COMPOSITION VOLTAGE DETECTOR (CCVD)

### 6.1 Present state of the Art

The CCVD described in Ref 3 had an upper frequency limitation of 500 MHz because the large physical size of the junction diode, used in the circuit, made it impossible to contain the instrumentation within the N 8 igniter body. Recently a much smaller point contact diode has become available which has enabled the instrumentation to be fitted directly into the N 8 body. This has increased the high frequency limitation from 500 MHz to 1.8 GHz and considerably simplified calibration. A report has been issued describing the new CCVD with reference to the conducting composition voltage indicator (CCVI) (Ref 4) and a schematic diagram of the instrumentation together with the circuit diagram are shown at Figs 20(a) and (b) respectively.

For use with the HME2 it is only necessary to place a passive resistance network between the CCVD and the data coding module in order that the d c signal produced by the CCVD can be treated in the same way as that from the thermistor bridge. The circuit of this network or adaptor is shown in Fig 21. The CCVD, adaptor and HME2 have been shown to operate satisfactorily under laboratory conditions but, in view of the current development of a peak measuring voltage detector, this equipment, which is only applicable to C W measurements, has not been the subject of the exhaustive trials undertaken on the bridge-wire equipment (Section 5.5).

Calibration of this new CCVD can be carried out in the laboratory before installation in the weapon as, with internally mounted components, environment will have little effect.

### 6.2 Future work

As the conducting composition device may be regarded as being voltage sensitive, functioning at very low energy inputs, and the present equipment, by monitoring the r m s voltage induced, measures power, Messrs EMI(E) have been asked to produce a peak voltage measuring equipment. The aim of this work, which has now commenced, is to produce instrumentation which is capable of measuring the voltage induced in a c c device exposed to a high power, pulsed radar; this equipment, like the CCVD will be capable of use with both the CCVI and the HME2.

## 7. CONCLUSIONS

A r f hazard measuring equipment has been described capable of measuring pick up, at levels at least 40 dB below threshold, in the two wire bridge devices in most common use viz, the ICI F53 fuse, electric and the RARDE Type 203 igniter. The instrumentation has been shown to have no effect on frequency response of the EIED up to about 7 GHz and an accuracy of approximately  $\pm 2$  dB up to this frequency has been demonstrated.

The equipment incorporates a remote 'zeroing' facility which allows ambient temperature compensation, under conditions of zero hazard, to be made during the course of a trial. The life of the inaccessible data coding module battery is three weeks which is considered ample for all practical applications.

For use with c c devices the upper frequency response of the CCVD has been increased from 500 MHz to 1.8 GHz and, using a simple adaptor, this detector can be used with the HME2. Work at Messrs EMI(E) has been undertaken to produce a peak voltage measuring detector suitable for use with both the HME2 and the CCVI.

## 8. BIBLIOGRAPHY

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3. RARDE Memorandum 33/69. Measurement of r f pick-up in Firing circuits. Instrumentation for conducting composition EIED. August 1969
4. EMI(E) Ltd. Report DMP 3490. Conducting Composition Voltage Indicator. September 1969.
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6. Ibid. DMP 2844 Final progress report into radio hazards to Explosives in guided weapons. June 1967.
7. Ibid. DMP 3217 Hazard Measuring Equipment Mk 2. August 1968
8. Ibid. DMP 3208 Final progress report into hazards to explosives in guided weapons. July 1968.

APPENDIX 1Hazard Measuring Equipment Mk IITechnical Specification1. GENERAL REQUIREMENTS

The Hazard Measuring Equipment is designed to measure, and indicate remotely, suitable parameters from which can be deduced the likelihood of EIED being fired by the pick-up of energy from electro-magnetic fields. The introduction of the detection equipment does not significantly alter the electro-magnetic environment of the EIED, nor the pick-up conditions.

2. MEASUREMENT METHOD USED

The relevant parameter for wire-bridge EIED is the temperature rise of the bridge-wire. A thermistor attached to the bridge-wire, is used to measure this in conjunction with a means for ambient temperature compensation. Fuzeheads which have not been coated with explosive material are used.

3. MEASUREMENT LIMITATION3.1 CW Sources3.1.1 Type 200 Igniters

The method described in para 2 is satisfactory at least over the band 100kHz to 5GHz.

3.1.2 Series F Fuses, Electric

The method described in para 2 is satisfactory at least over the band 100kHz to 2GHz.

3.2 Pulsed Sources

As for cw provided only that the time between successive pulses is significantly less than the thermal time-constant of the device instrumented.

4. SENSITIVITY

A sensitivity could be defined in terms of the temperature rise of the thermistor bead. However, this is not the same as the temperature rise of the bridge-wire differing from it by an unknown amount. Consequently it is preferable to express the detector sensitivity in terms of the rms current in the bridge-wire of a specific device. In all cases the dynamic range of the equipment is sufficient to read current up to 26dB greater than the minimum measurable current.

4.1 Type 203 Igniters

The minimum measurable current will be less than 15mA.

4.2 F53 Fuses, Electric

The minimum measurable current will be less than 3mA.

## 5. ACCURACY

It is estimated that the overall system accuracy is better than  $\pm$  2dB of the indicated value of current.

## 6. DATA LINK TO REMOTE INDICATOR

### 6.1 Magnetic Coupling

Since certain parts of the equipment will be inside the missile being tested, and the rest external (perhaps at some distance) some means of interconnection will be necessary. In order to transfer the data from the interior of the missile to the exterior without making any breaks in the existing screening, a magnetic coupling is usual. This has the ability to couple through cast iron up to 0.4 inches in thickness, and non-ferrous material up to 4 inches thick.

### 6.2 Trailing Cables

It may sometimes be desirable to connect the magnetic pick-up to the remote indicator by means of a cable. This cable is double braided and fitted with well screened connectors.

### 6.3 Acoustic Link

#### 6.3.1 Description

In order to avoid disturbance of the rf environment of the missile, an acoustic data link can be used between the magnetic coupling external to the missile and a remote point. This link utilizes acoustic transmission down a plastic tube with adequately screened transducers at either end. At the receiving end a double braided cable is used to connect to the indicator unit.

#### 6.3.2 Range

The acoustic portion of the data link has a standard length of 10 feet. The double braided cable has a standard length of 48 feet. Both these lengths may be increased considerably if additional parts are manufactured.

#### 6.3.3 Acoustic Environment

The acoustic data link is not disturbed by normal outdoor noise levels as experienced at radio hazard trials.

#### 6.3.4 Use Without Magnetic Link

In cases where the missile does not have an outer screen or complete skin, the magnetic coupling may be omitted from the data link.

## 7. POWER SUPPLIES

### 7.1 Indicator Unit

The indicator unit is powered by a rechargeable battery giving approximately 72 hours operation per charge.

7.2 Modules

All units apart from the indicator unit are powered by individual batteries having an operating life of approximately 500 hours.

8. ENVIRONMENT8.1 Ambient RF Fields

All units are capable of operation in rf fields of the intensity found in the vicinity of radio and radar equipments the output frequencies of which may lie in the range 100kHz to at least 11GHz.

8.2 Ambient Temperature

The equipment will function satisfactorily over an ambient temperature range of 0°C to 30°C.

9. INSTALLATION9.1 Interconnection

The modules within the missile need to be interconnected but no limitations exist on the lengths of these leads.

9.2 Instrumentation of EIED

Instrumentation of wire-bridge igniters should not be attempted in the field but it is possible to replace instrumented devices if required for a particular trial. The attachment of the instrumentation to the bridge-wire device in particular is a skilled operation, but requires no ability which cannot be acquired after a short course of instruction.

10. CALIBRATION

Calibration is carried out on site by injecting known amounts of dc into the igniter firing leads.

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FIG. I

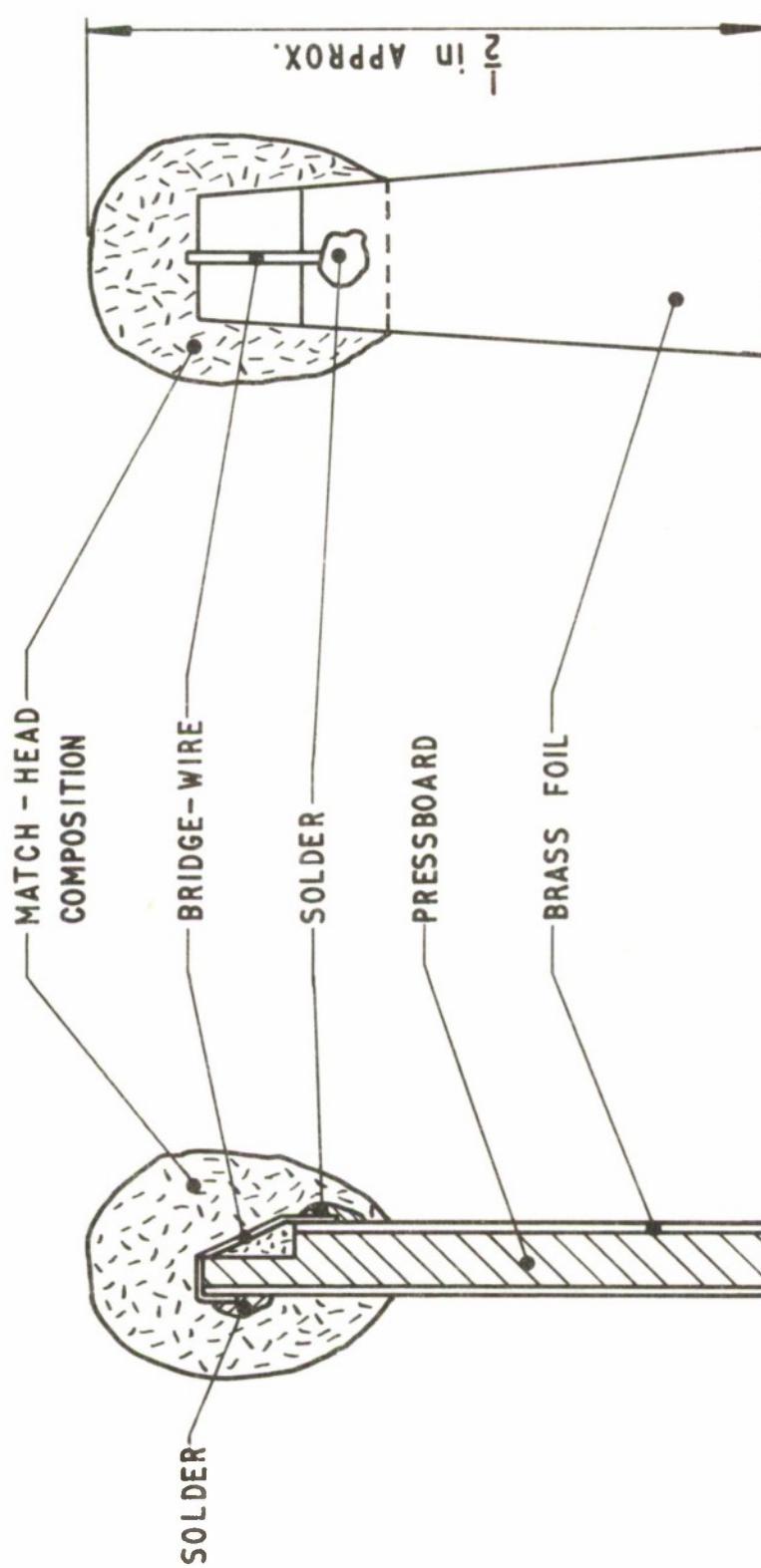


FIG. I LOW TENSION ELECTRIC FUSEHEAD

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FIG. 2

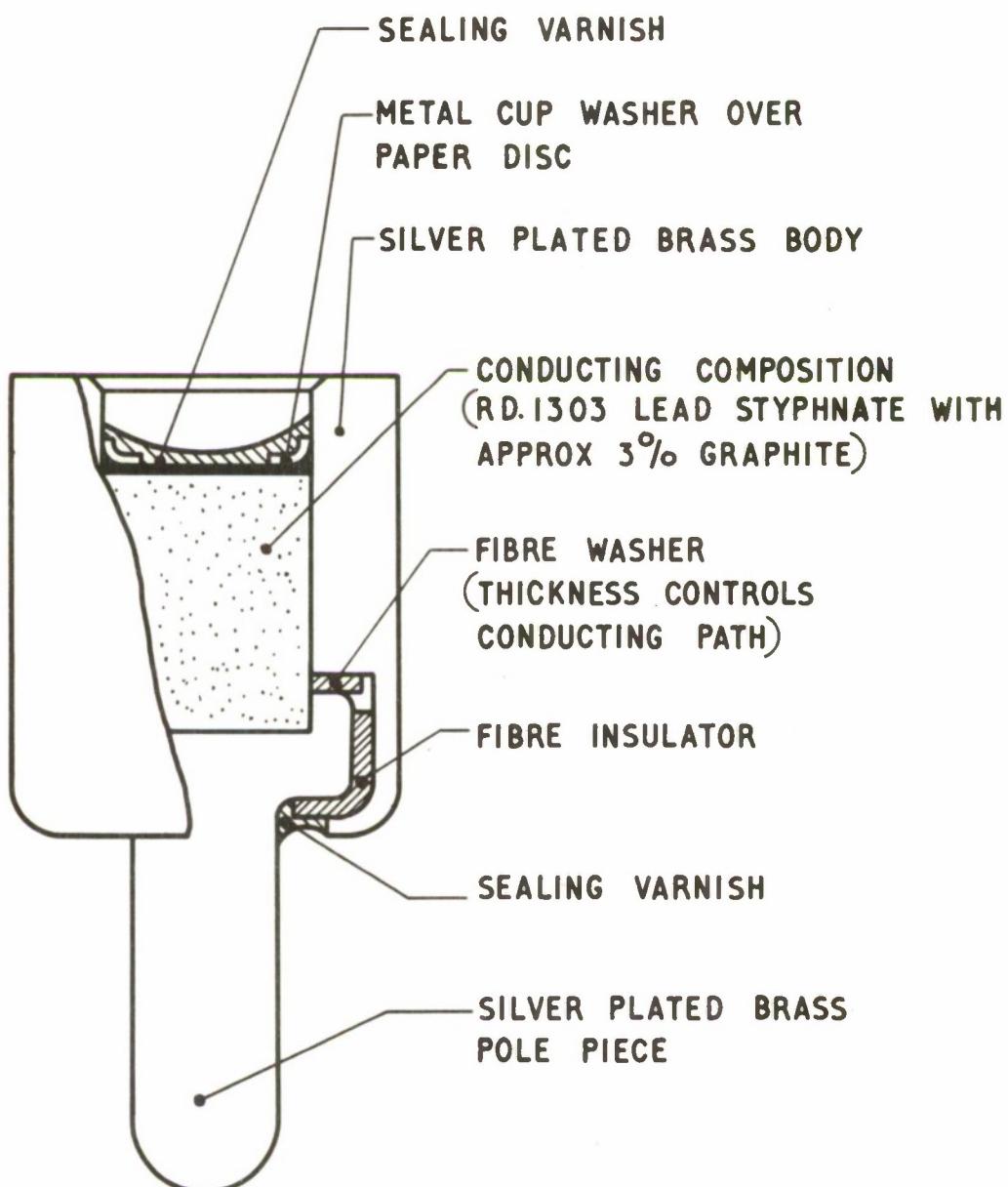


FIG. 2 MAIN FEATURES OF THE N.8 IGNITER

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FIG. 3

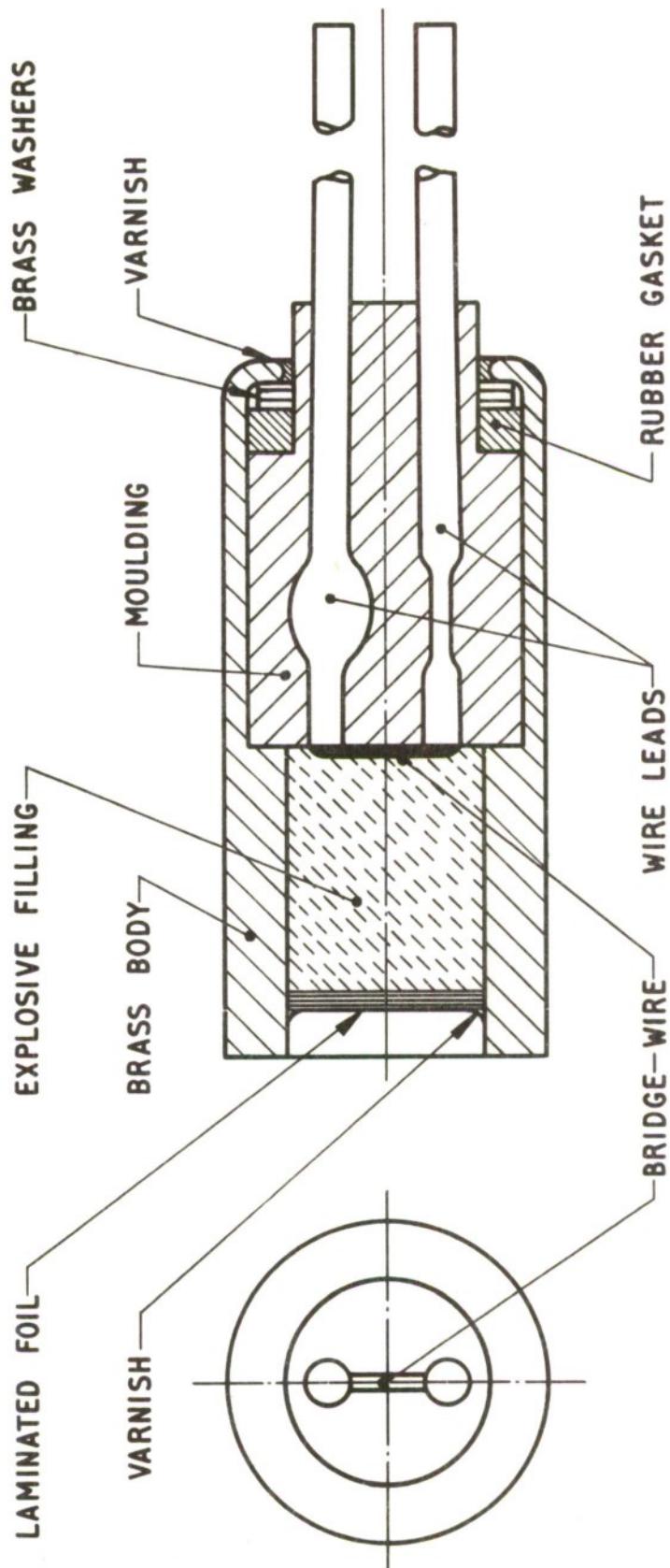
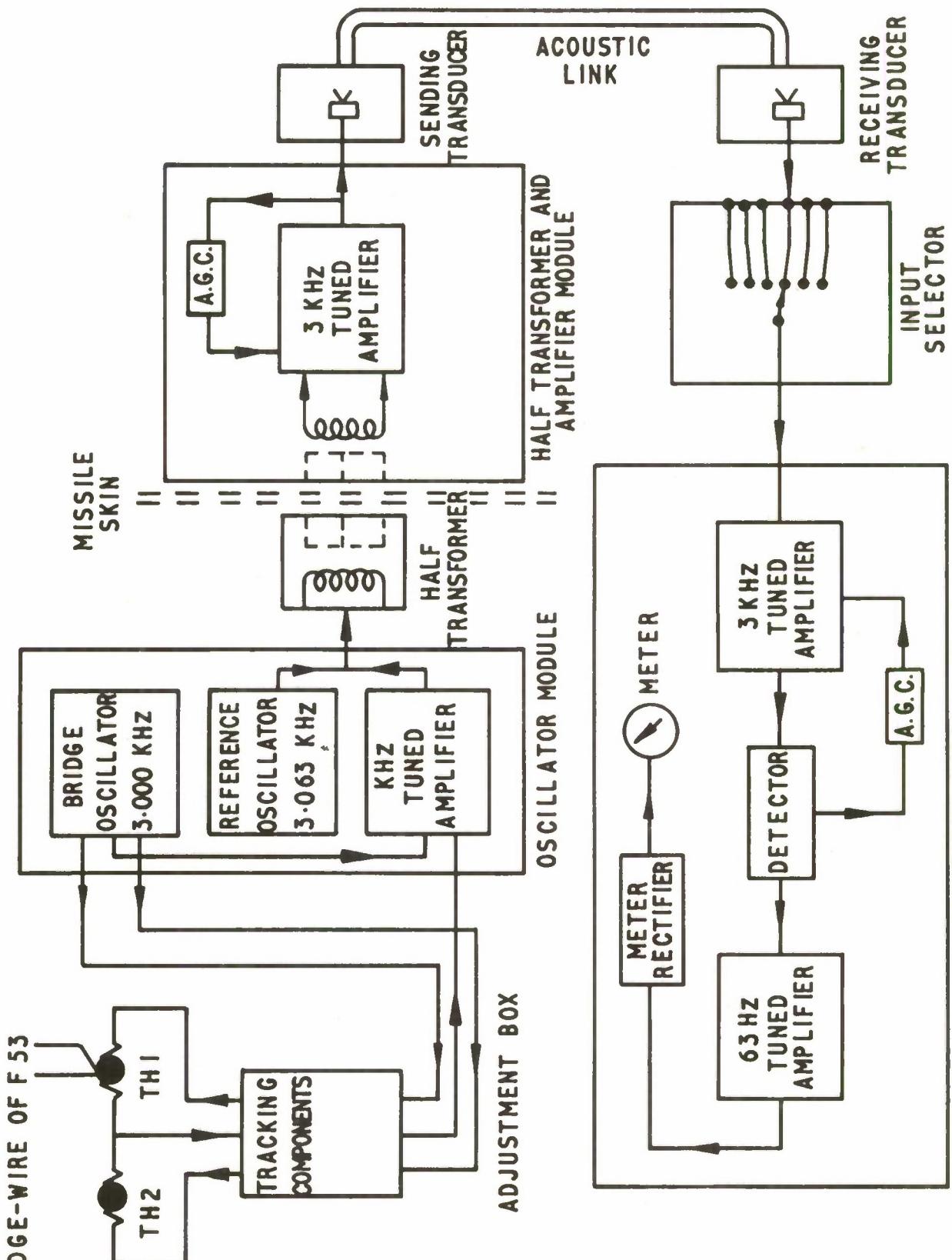


FIG. 3 TYPE 203 ENCLOSED BRIDGE-WIRE IGNITER

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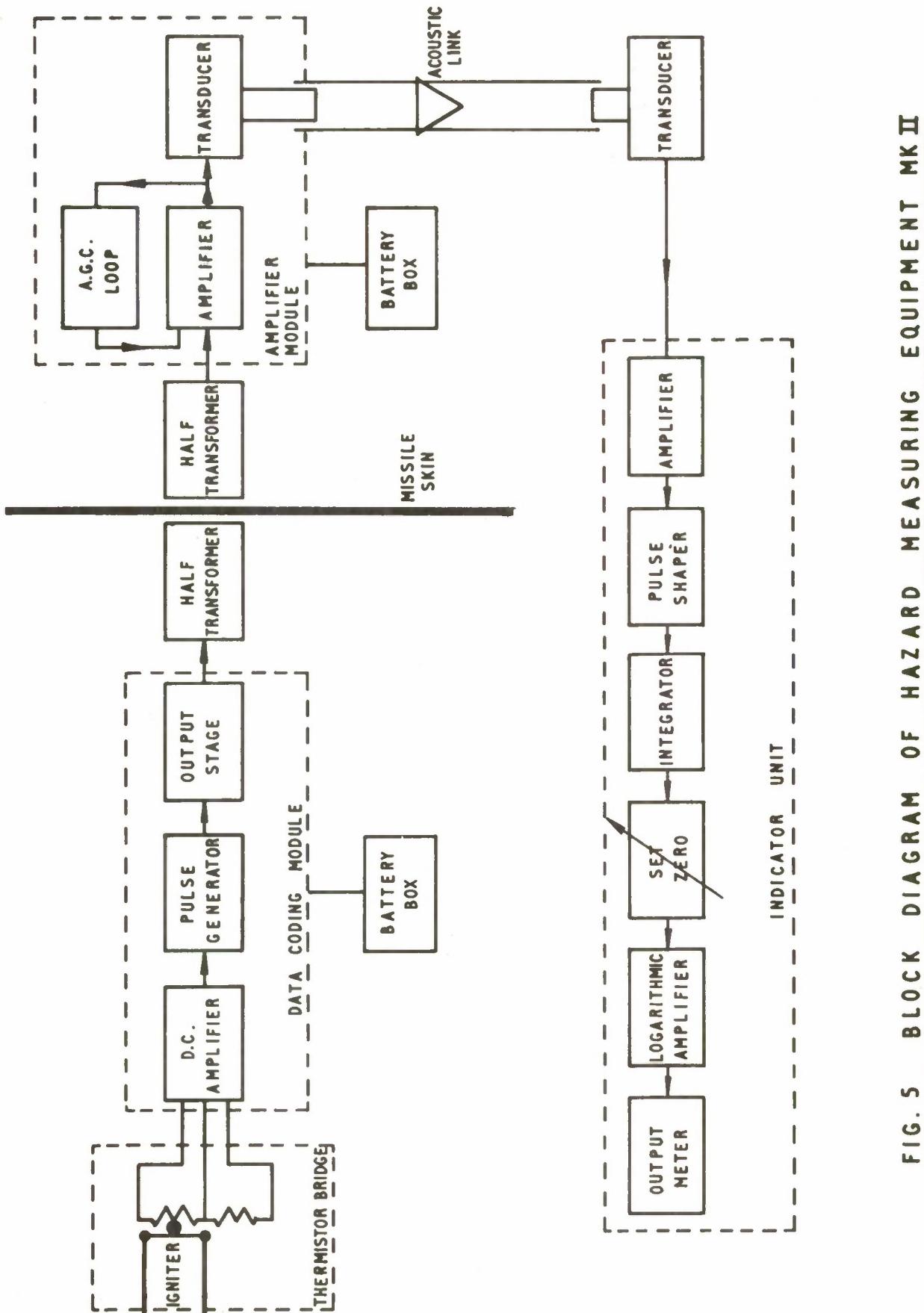
FIG. 4



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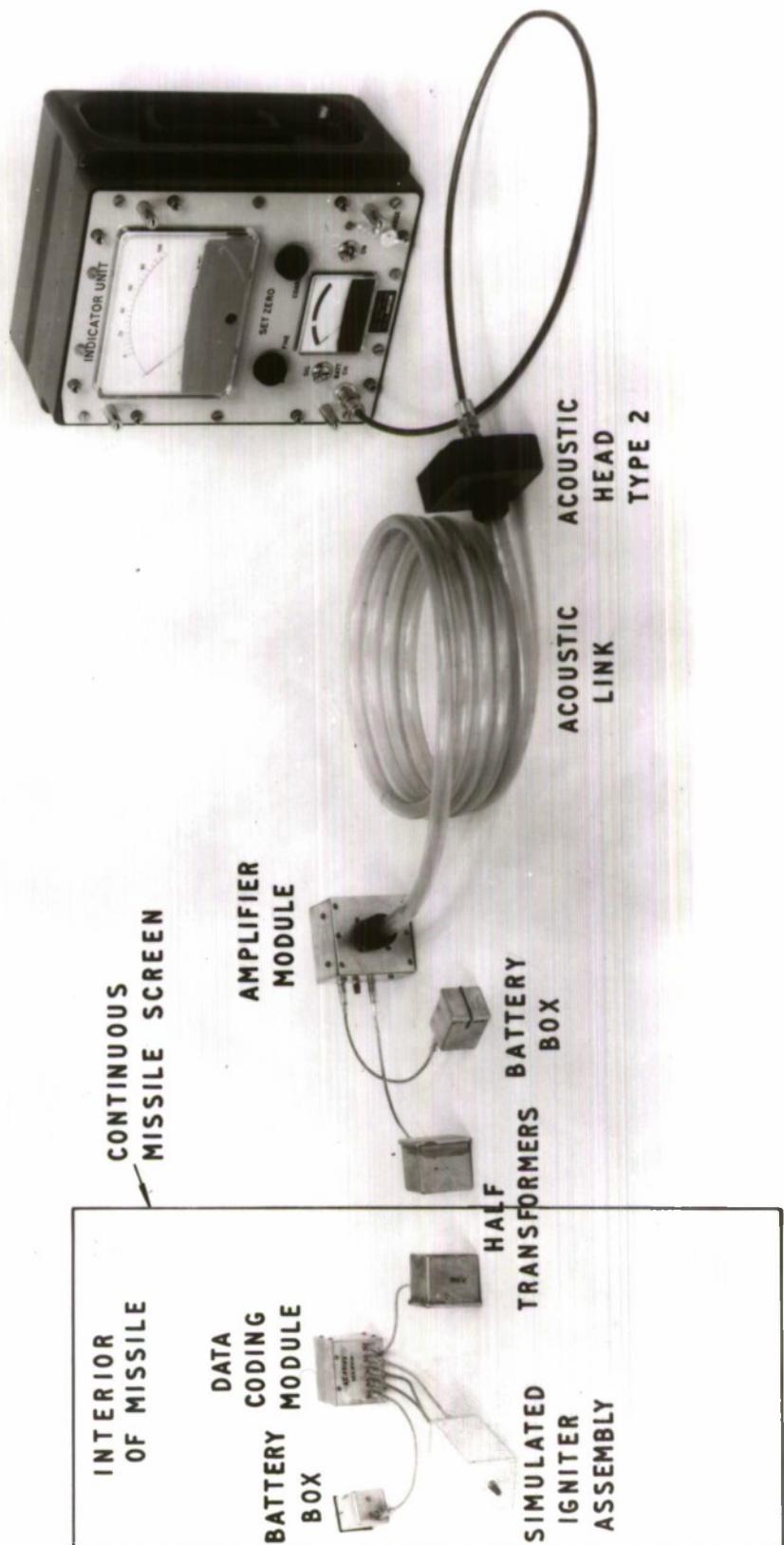
FIG. 5



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FIG. 6

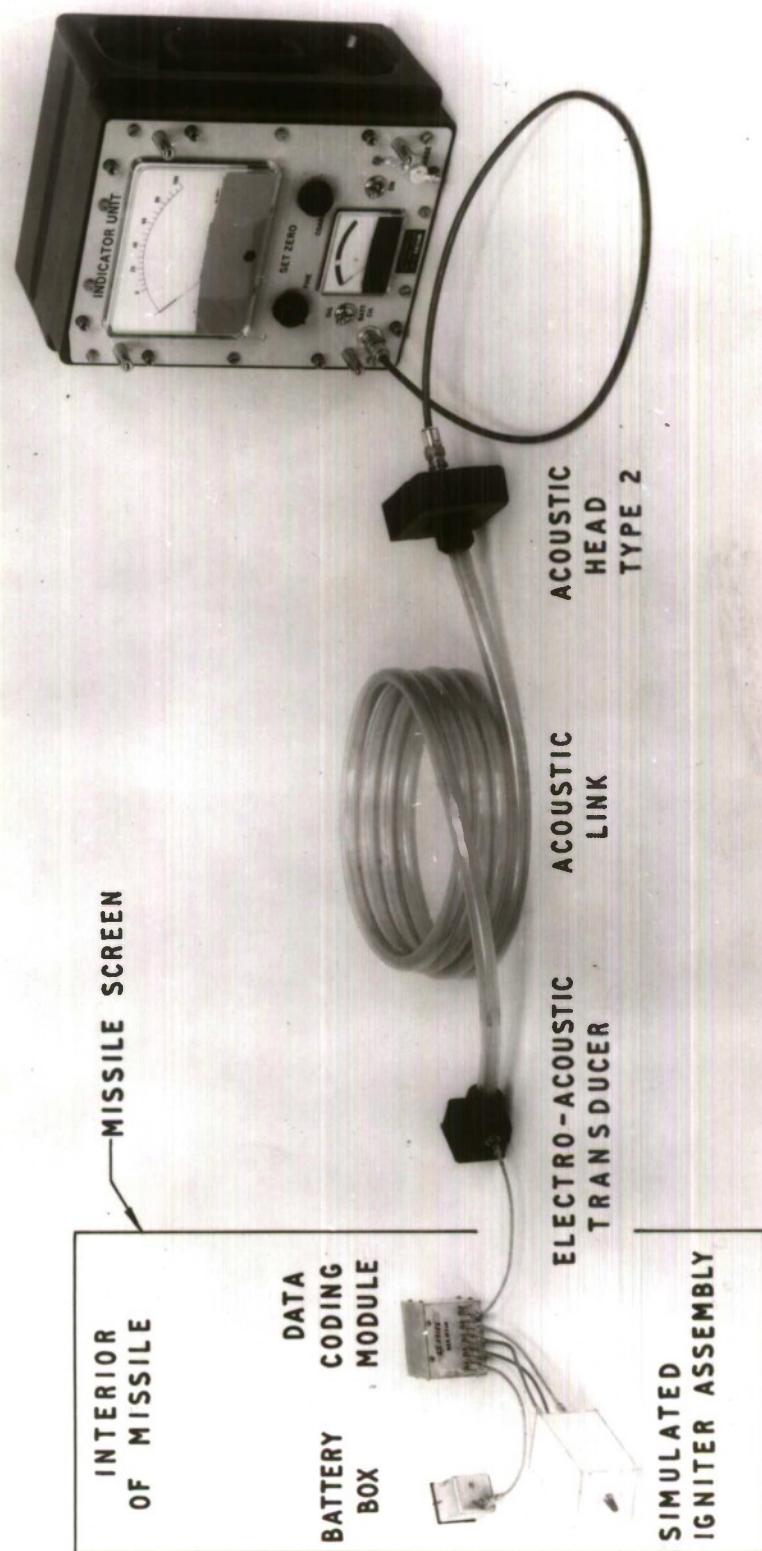


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FIG. 6 HAZARD MEASURING EQUIPMENT MK II

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FIG. 7



ALTERNATIVE GENERAL ARRANGEMENT

FIG. 7 HAZARD MEASURING EQUIPMENT MK II

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FIG. 8

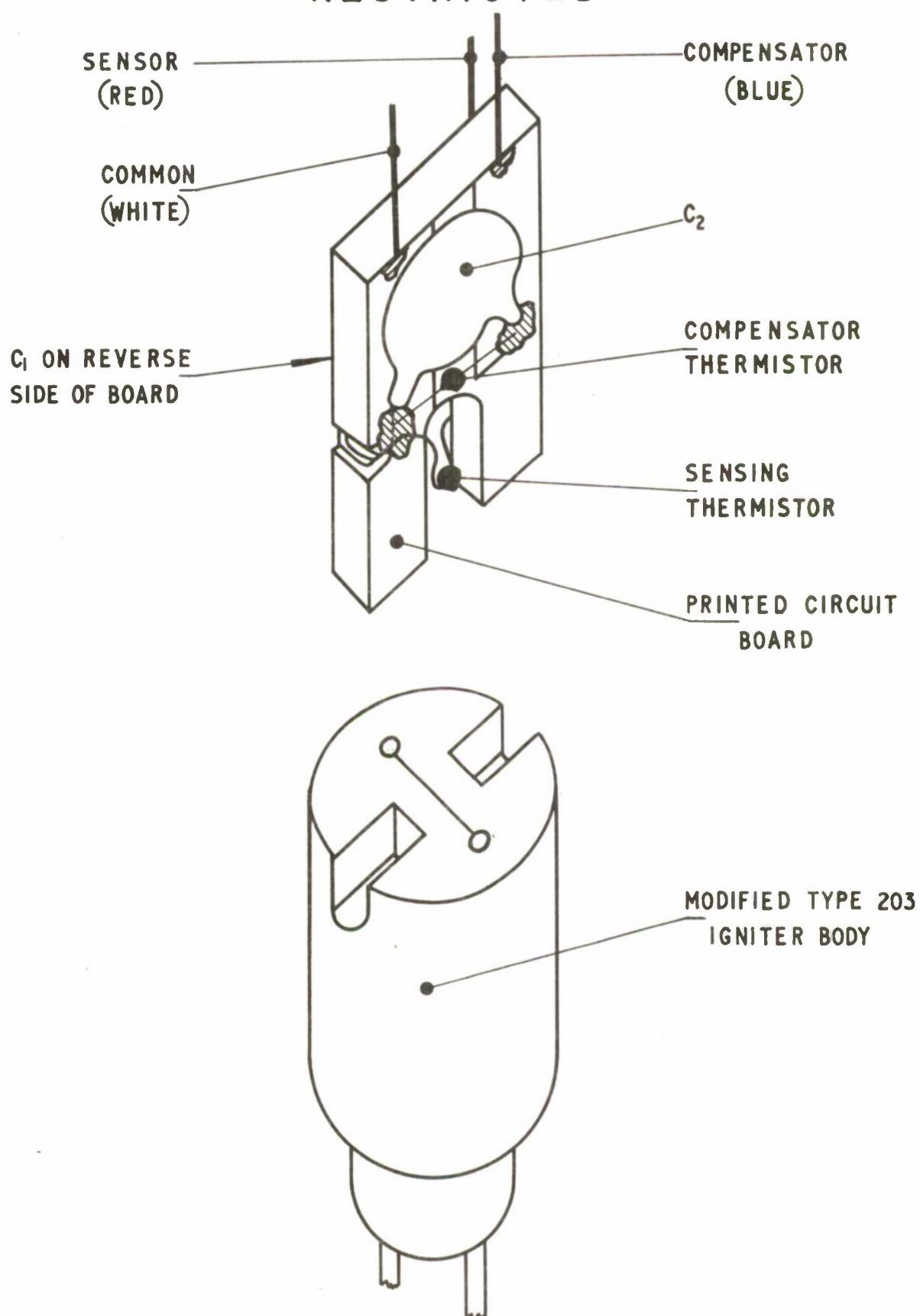
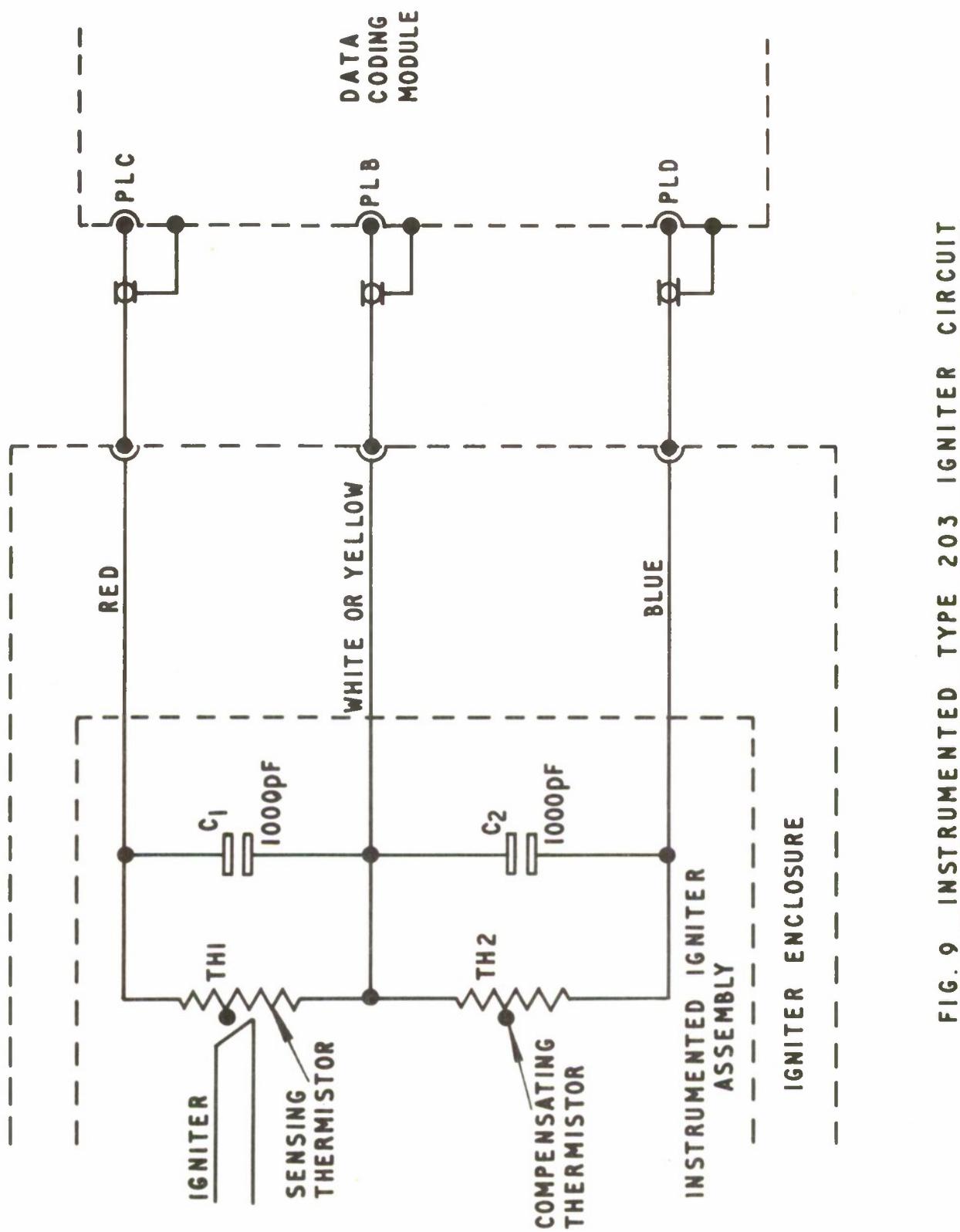


FIG. 8 INSTRUMENTED TYPE 203 IGNITER ASSEMBLY

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FIG. 9

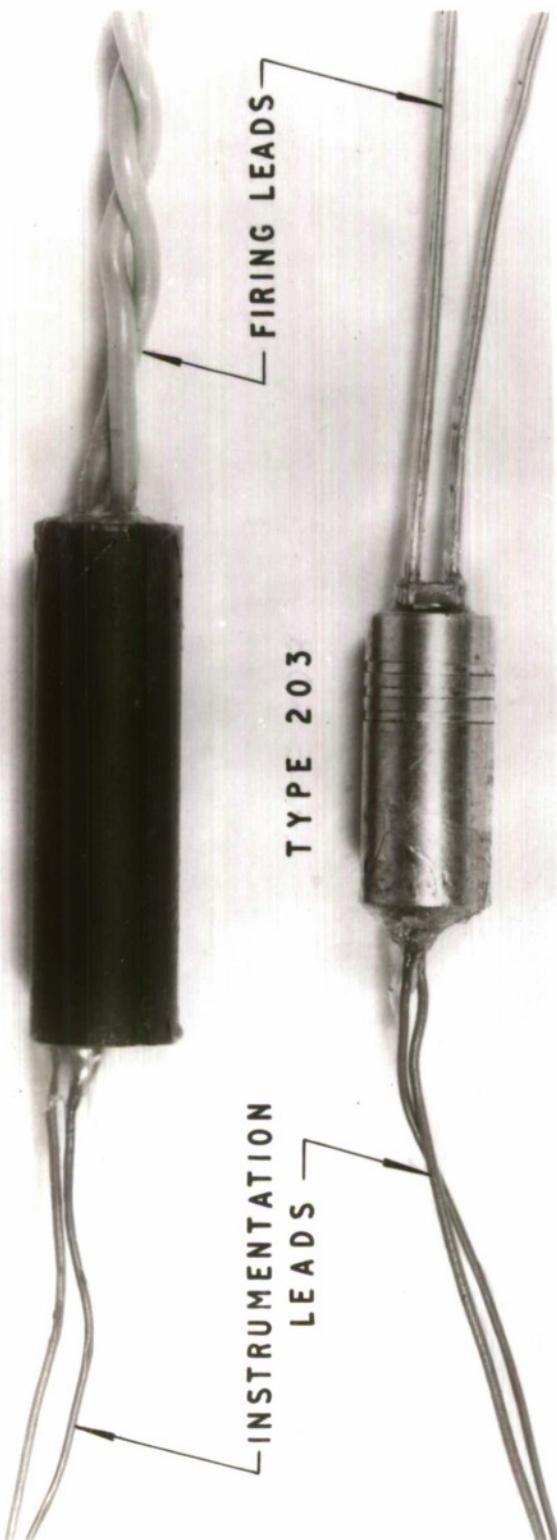


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FIG.10

F53 FUSE, ELECTRIC



CENTIMETRE

	1	2	3	4	5

FIG.10 INSTRUMENTED IGNITERS

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FIG. II

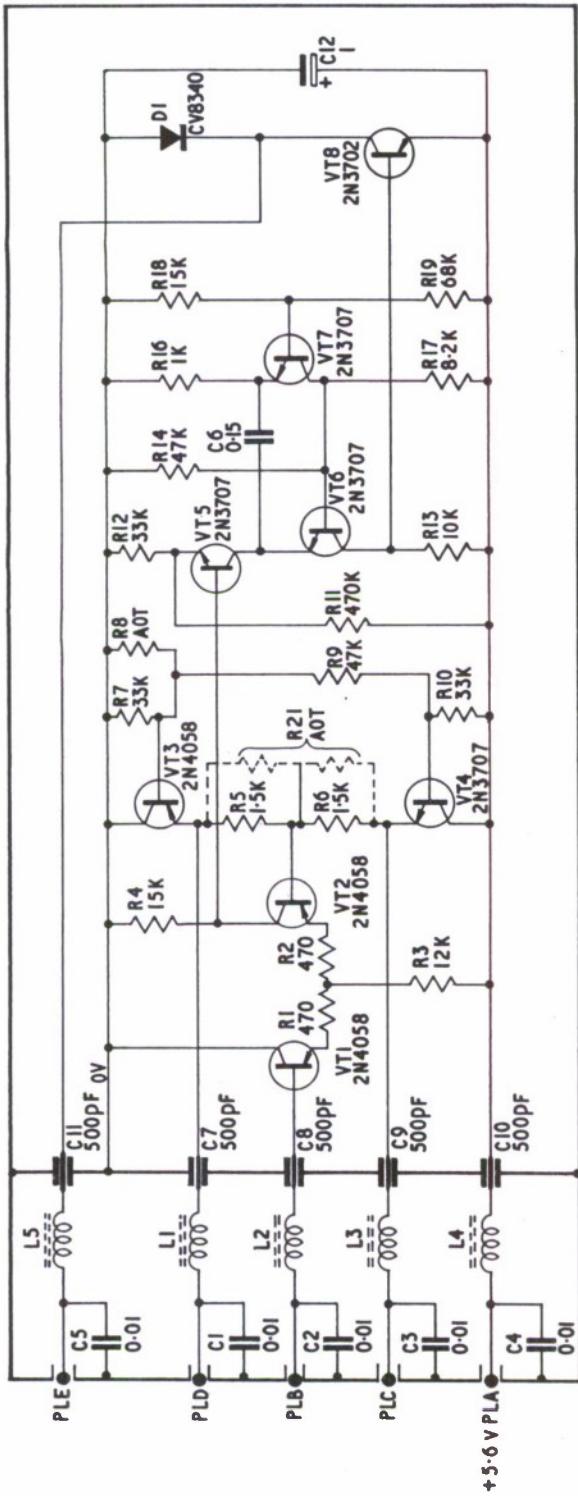


FIG. II DATA CODING MODULE — CIRCUIT DIAGRAM

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FIG. 12

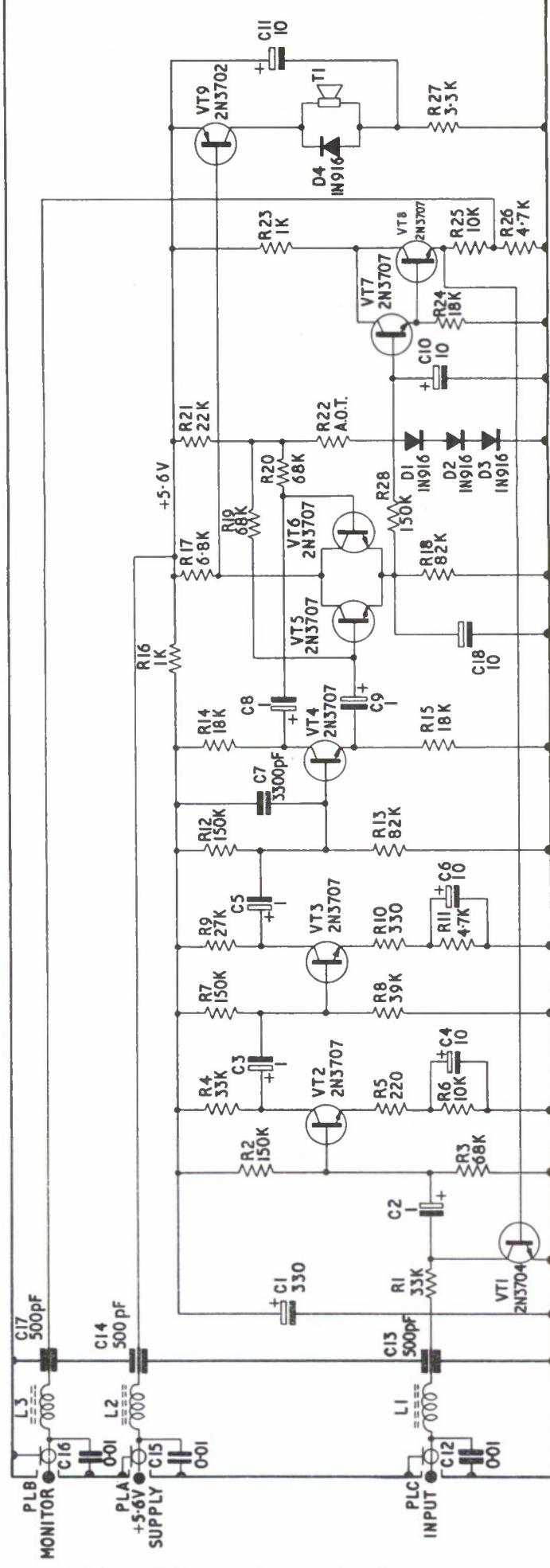


FIG. 12 AMPLIFIER MODULE—CIRCUIT DIAGRAM

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FIG. 13

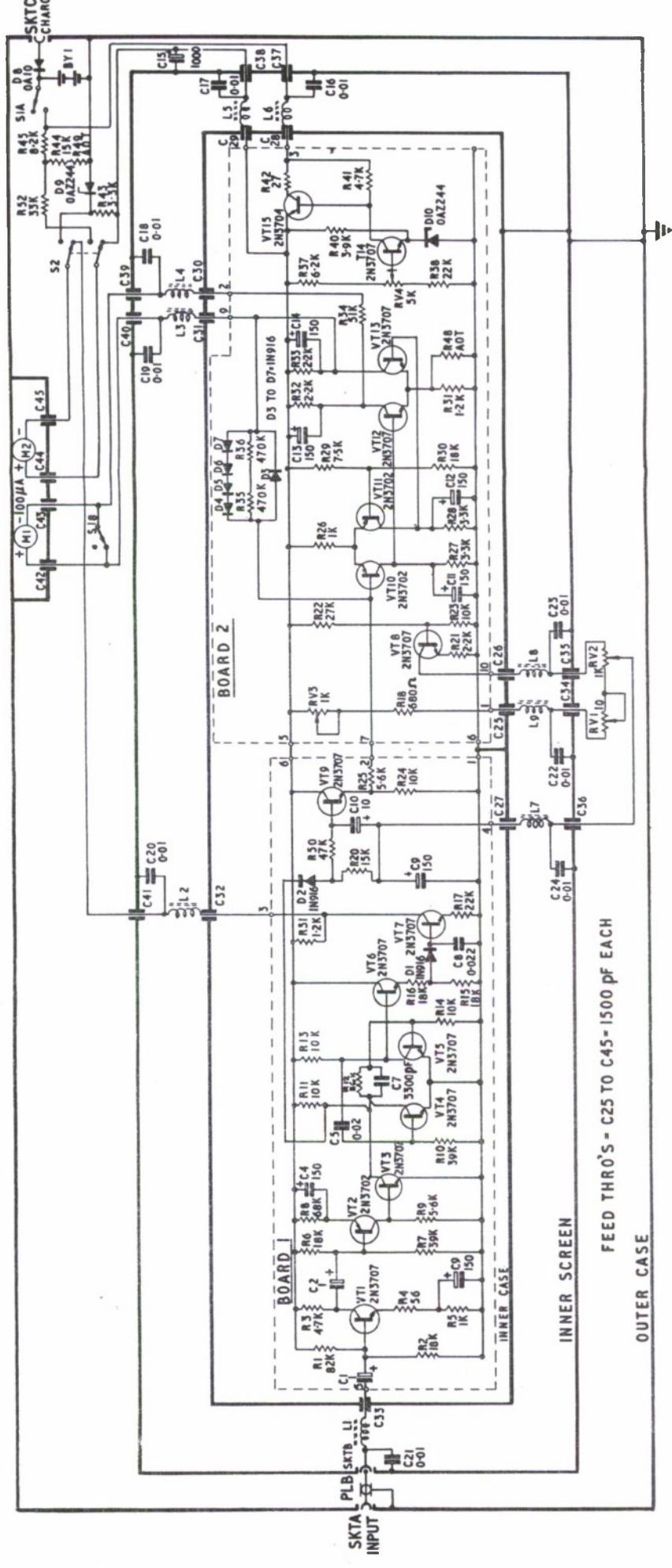
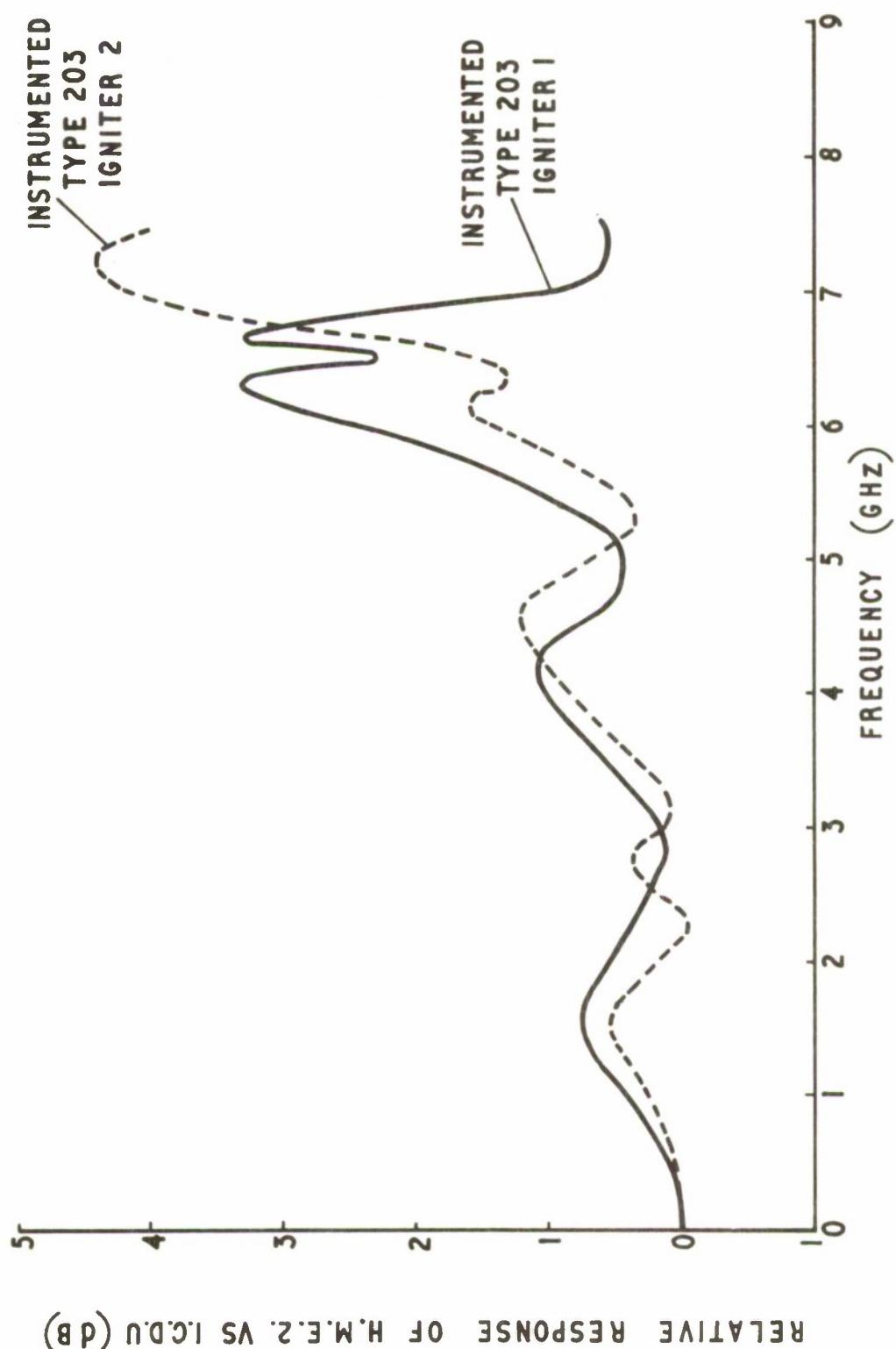


FIG. 13 INDICATOR UNIT - CIRCUIT DIAGRAM

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FIG.14



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FIG.14 COMPARISON OF H.M.E.2. AND I.C.D.U. FOR TYPE 203 IGNITERS

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FIG. 15

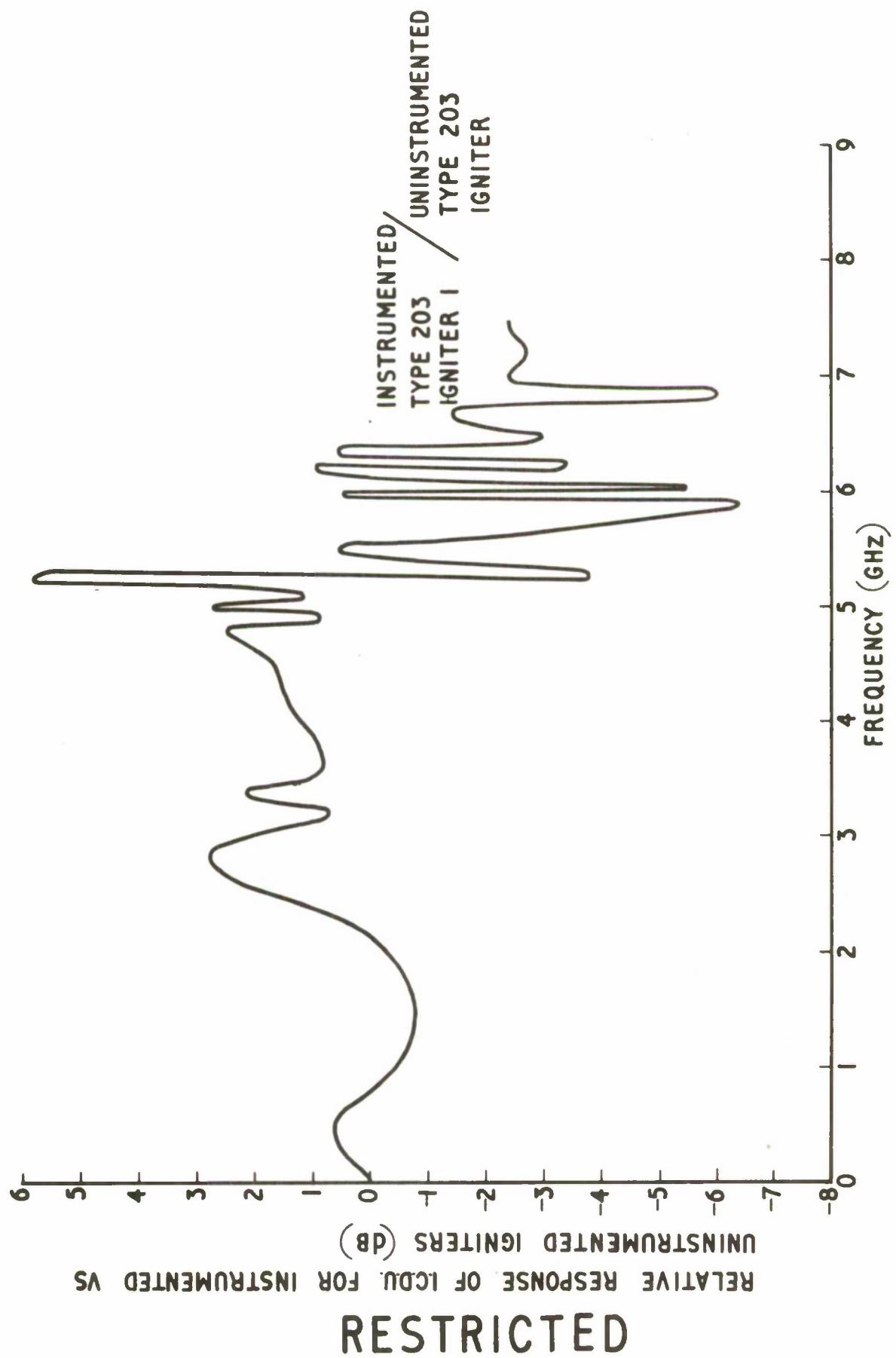
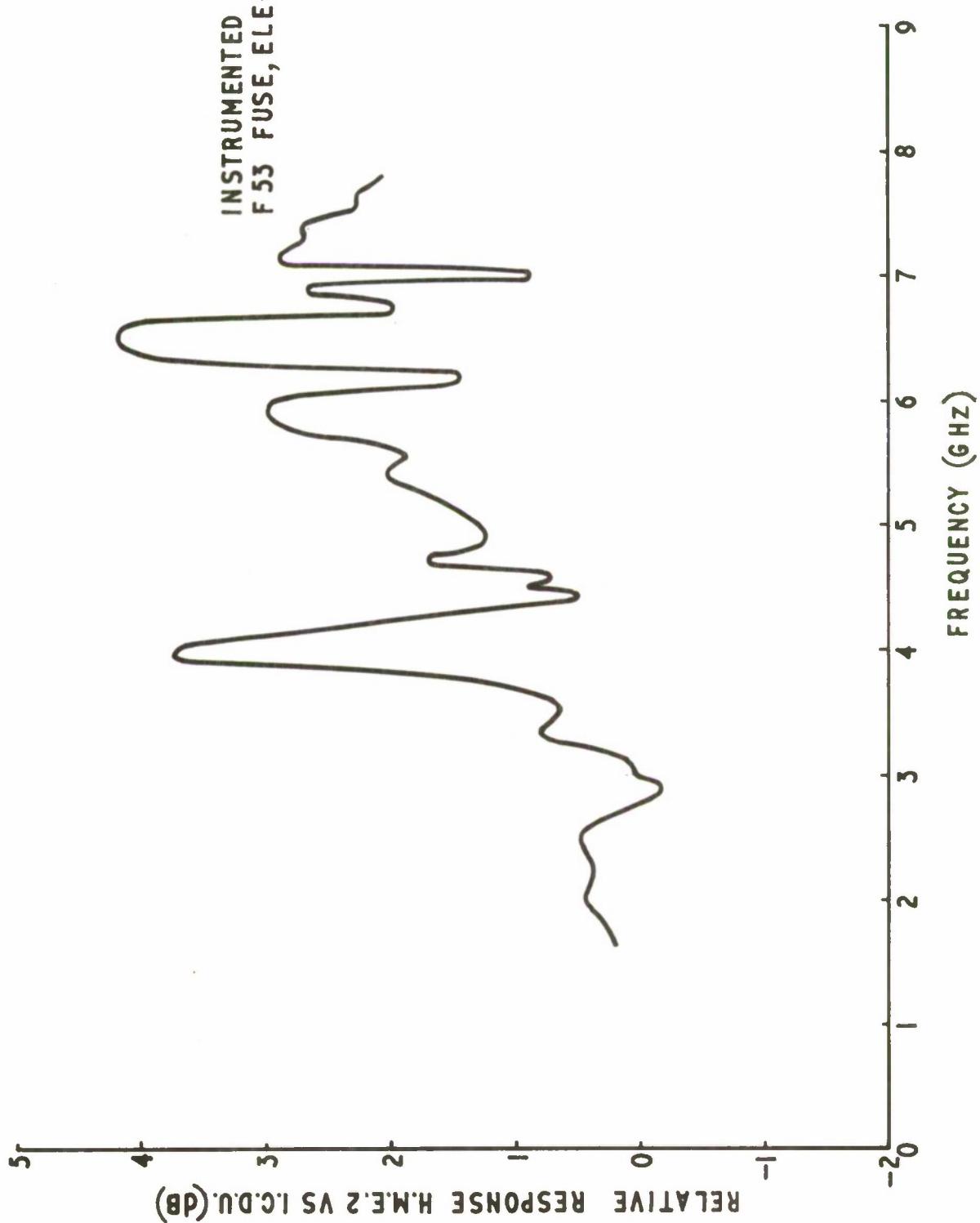


FIG. 15 COMPARISON OF INSTRUMENTED AND UNINSTRUMENTED TYPE 203 IGNITERS USING I.C.D.U.

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FIG.16

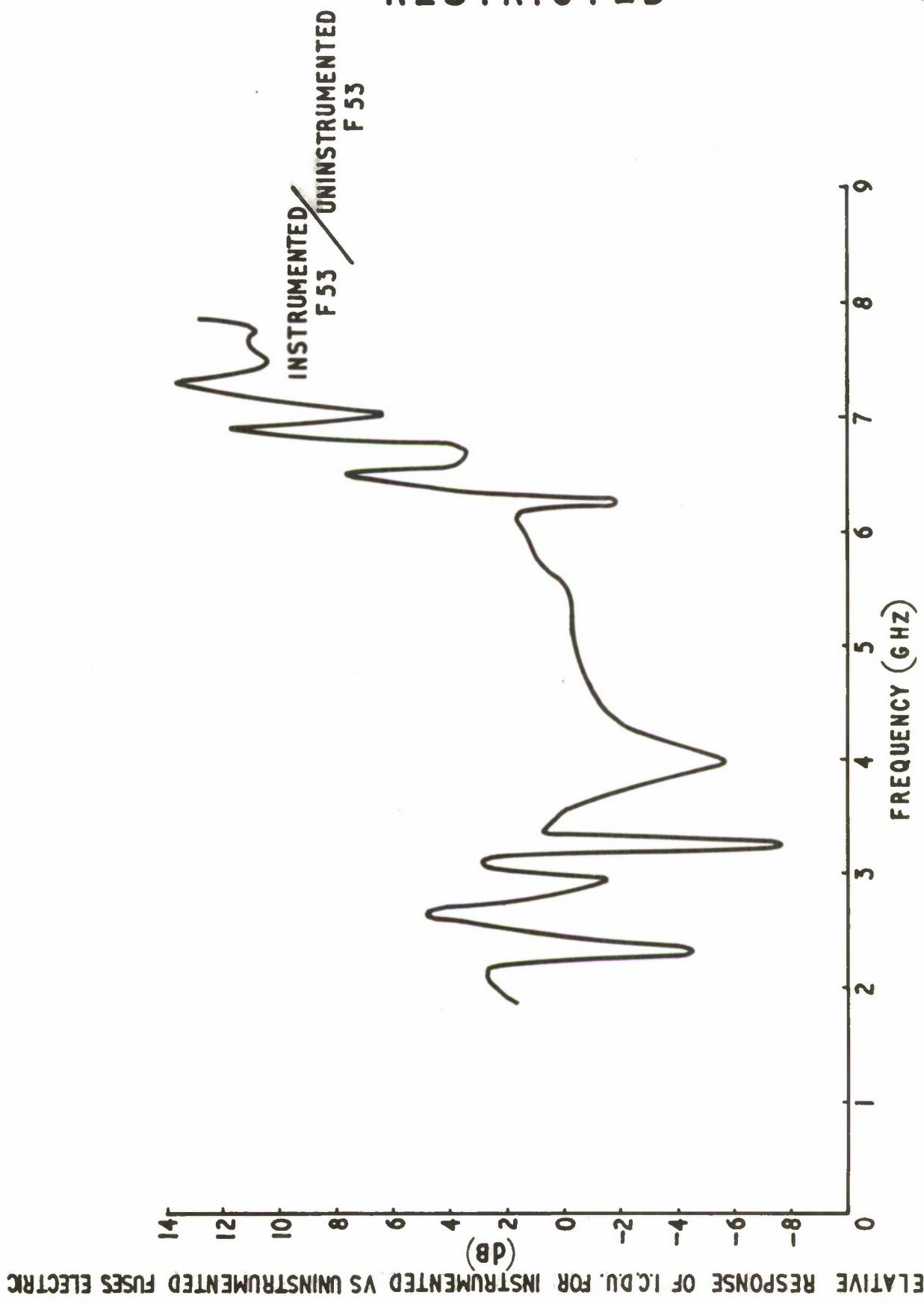


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FIG.16 COMPARISON OF H.M.E. 2 AND I.C.D.U. FOR F 53 FUSE, ELECTRIC

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FIG.17



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FIG.17 COMPARISON OF INSTRUMENTED AND UNINSTRUMENTED F53 FUSES, ELECTRIC, USING I.C.D.U.

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FIG. 18

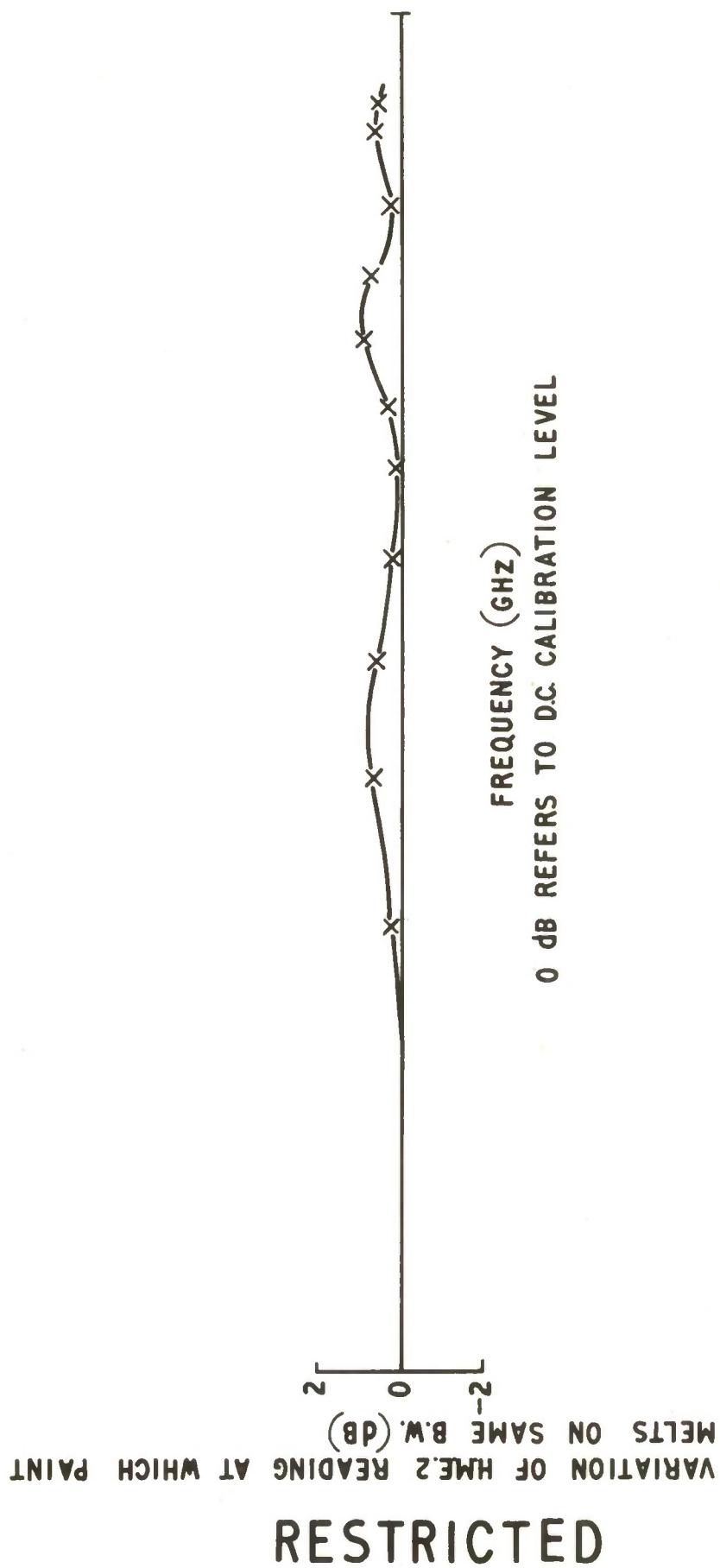


FIG. 18 FREQUENCY RESPONSE HME.2 FITTED TO TYPE F53 FUSE, ELECTRIC

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FIG. 19

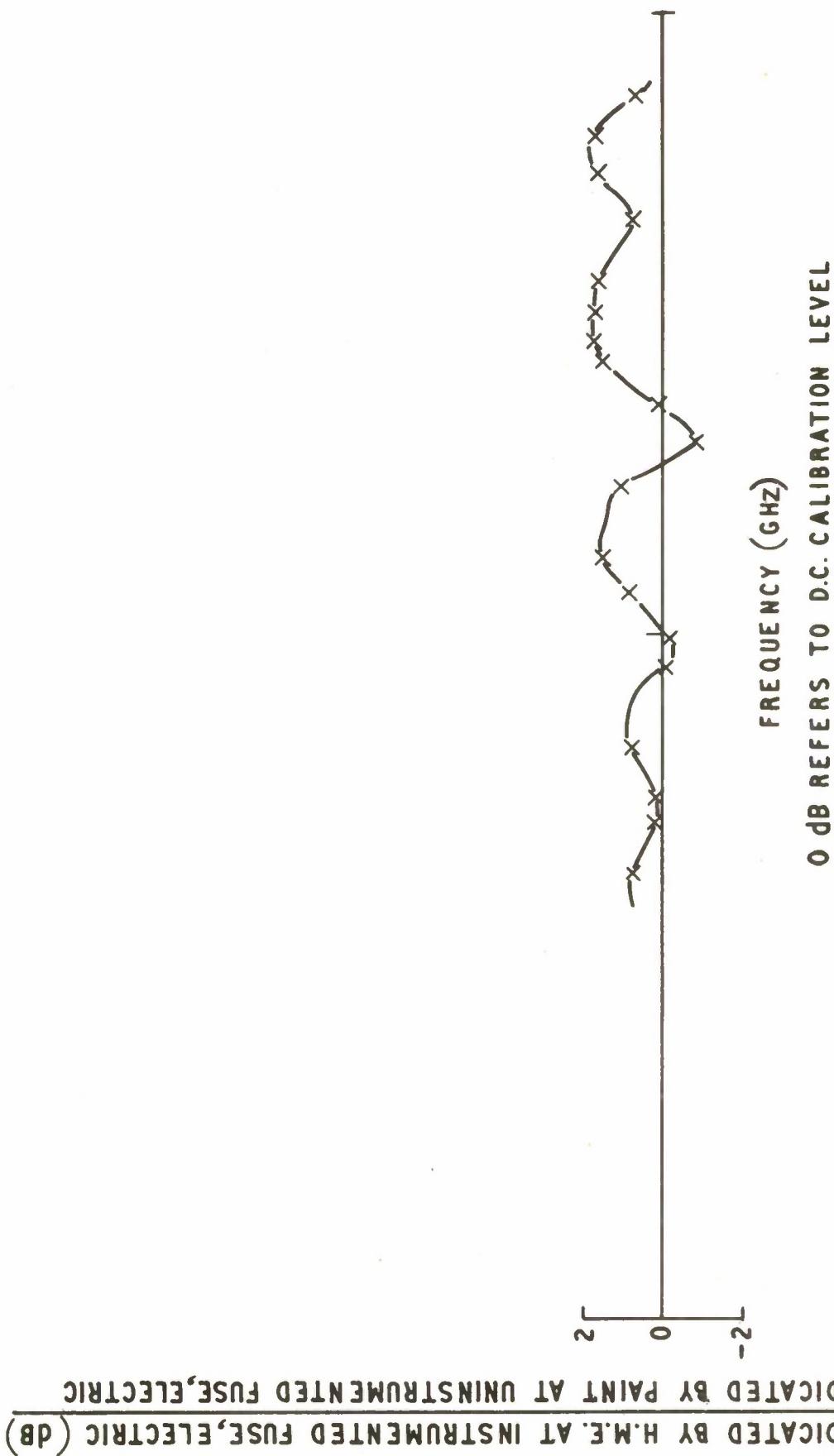


FIG. 19 RELATIONSHIP BETWEEN POWER AT INSTRUMENTED AND UNINSTRUMENTED FUSES, ELECTRIC, FED FROM THE SAME R.F. SOURCE

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FIGS.20(a)(b)

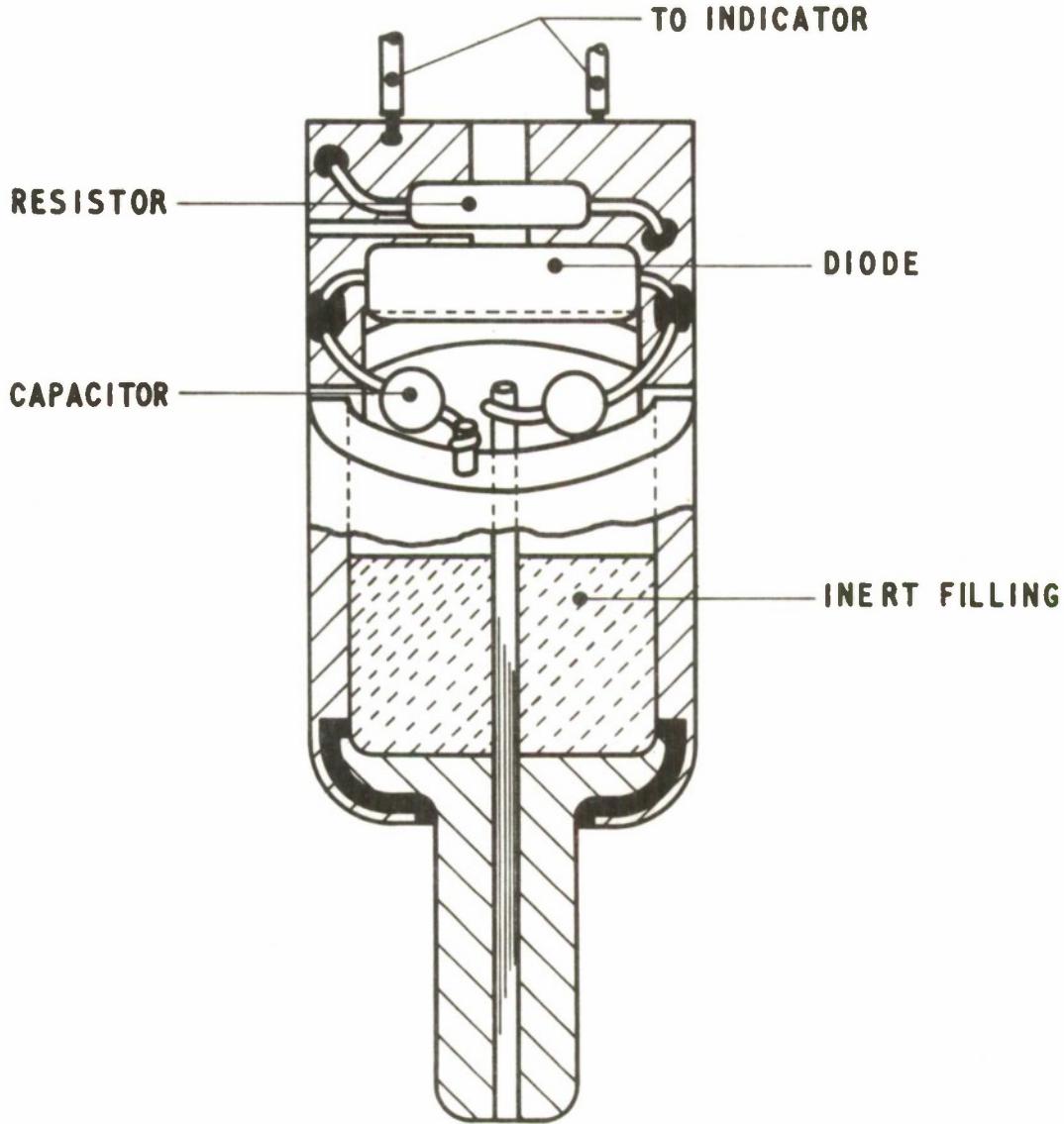


FIG.20 (a) ARRANGEMENT OF C.C. VOLTAGE DETECTOR

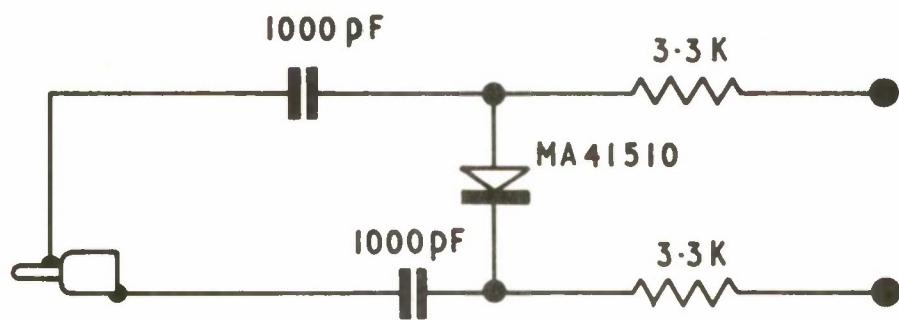


FIG. 20(b) CIRCUIT DIAGRAM OF C.C. VOLTAGE DETECTOR

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FIG. 21

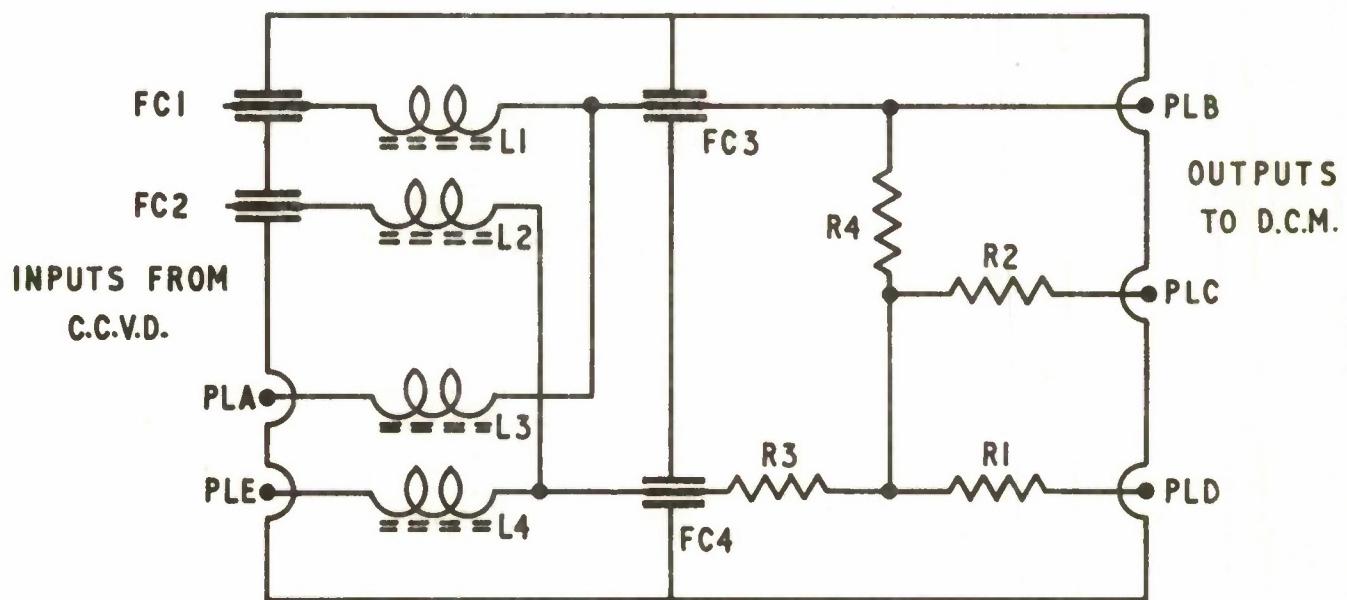


FIG. 21 CIRCUIT DIAGRAM OF C.C.V.D. ADAPTOR UNIT

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RESTRICTED	623.454.242-83: 621.396.029.5 R.A.R.D.E. Memorandum 10/70	Ministry of Defence Royal Armament Research and Development Establishment R.A.R.D.E. Memorandum 10/70	RESTRICTED	623.454.242-83: 621.396.029.5
Measurement of RF pick up. Improved equipment for assessment of RF hazard in firing circuits of weapons containing wire-bridge electrically initiated explosive devices (EIED). (Title UNCLASSIFIED) W. L. Watton Edited by M. G. Brown	July 1970	Measurement of RF pick up. Improved equipment for assessment of RF hazard in firing circuits of weapons containing wire-bridge electrically initiated explosive devices (EIED). (Title UNCLASSIFIED) W. L. Watton Edited by M. G. Brown	July 1970	Measurement of RF pick up. Improved equipment for assessment of RF hazard in firing circuits of weapons containing wire-bridge electrically initiated explosive devices (EIED). (Title UNCLASSIFIED) W. L. Watton Edited by M. G. Brown
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they are integrated and displayed as a d c signal on the hazard meter. A remote 'zeroing' facility is provided at the indicator unit allowing the bridge to be balanced under conditions of zero hazard.

This memorandum describes work carried out by Messrs EMI (Electronics) Ltd under Min Tech contract No. KV/B/378/CB64(a). It is one of the series entitled "EIED and RF Hazards" and is based upon material published, on limited circulation, in Refs 4, 5, 6, 7 and 8.

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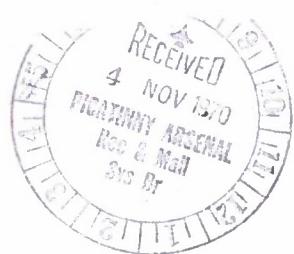
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